Study Report 98-03

Design of an Econometric Module to Support the ODCSPER Strength Management Systems Redesign

Patrick C. Mackin
SAG Corporation

Paul F. Hogan
The Lewin Group, Inc.

Peter M. Greenston
U.S. Army Research Institute

United States Army Research Institute for the Behavioral and Social Sciences

January 1998

U.S. Army Research Institute for the Behavioral and Social Sciences

A Directorate of the U.S. Total Army Personnel Command

EDGAR M. JOHNSON
Director

Research accomplished under contract
for the Department of the Army

Human Resources Research Organization

Technical Review by

David Byrne, American University
Abraham Nelson, ARI

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REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) 20-03-98	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) July 1996 to April 1997
4. TITLE AND SUBTITLE Design Of An Econometric Module To Support The ODCSPER Strength Management Systems Redesign		5a. CONTRACT OR GRANT NUMBER MDA903-93-D-0032 5b. PROGRAM ELEMENT NUMBER 65803
6. AUTHOR(S) Patrick C. Mackin, SAG Corporation Paul F. Hogan, The Lewin Group Peter M. Greenston, ARI		5c. PROJECT NUMBER D730 5d. TASK NUMBER 1331 5e. WORK UNIT NUMBER H2
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Human Resources Research Organization (HumRRO) 66 Canal Center Plaza, Suite 400 Alexandria, VA 22314		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) 5001 Eisenhower Avenue Alexandria, VA 22333-5600		10. MONITOR ACRONYM ARI 11. MONITOR REPORT NUMBER Study Report 98-03
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		
13. SUPPLEMENTARY NOTES Contracting Officer's Representative: Peter M. Greenston		

14. ABSTRACT *(Maximum 200 words)*:

This study assessed alternative approaches to incorporating an econometric module in ODCSPER's redesigned strength management system. It includes an examination of the operation of the strength management system and an assessment of the analytical needs of strength planners. The study also looked at available econometric methodologies and results available in the literature. These findings were integrated with an evaluation of the major management issues for individual Army personnel communities.

Study findings include a recommendation on the module's design specification, with description of key module algorithms and identification of appropriate econometric models and parameters. Other results include an evaluation of existing empirical parameters and recommendations for future econometric research to provide the module with new and improved parameters.

15. SUBJECT TERMS
Army strength management planning; retention modeling; econometrics; personnel; software design

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON (Name and Telephone Number)
16. REPORT Unclassified	17. ABSTRACT Unclassified	18. THIS PAGE Unclassified	Unlimited	69	Peter M. Greenston 703-617-0344

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Patrick C. Mackin
SAG Corporation

Paul F. Hogan
The Lewin Group, Inc.

Peter M. Greenston
U.S. Army Research Institute

Organization and Personnel Resources Research Unit
Paul A. Gade, Chief

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

March 1998

Army Project Number
20665803D730

Personnel and Training
Analysis Activities

FOREWORD

The Strength Management Division / DCSPER is upgrading the capability and performance of the Army's strength management planning systems. In conjunction with the automation upgrade, Army managers are also considering the addition of policy-analytic capabilities to the upgraded system. This report describes the design considerations and recommendations for including a behaviorally driven retention model as the core of that capability.

Zita M Simutis

ZITA M. SIMUTIS
Technical Director

DESIGN OF AN ECONOMETRIC MODULE TO SUPPORT THE ODCSPER STRENGTH MANAGEMENT SYSTEMS REDESIGN

EXECUTIVE SUMMARY

Research Requirement:

The Office of the Deputy Chief of Staff for Personnel is redesigning its strength management models used for officer and enlisted strength planning. This redesign effort provides the opportunity to add capabilities to the modeling system.

The purpose of this paper is to provide recommendations concerning the design of an econometric module or set of modules for the redesigned strength management models. The econometric elements of the system will provide the capability to adjust forecasts of the voluntary retention of soldiers in response to anticipated changes in military compensation, civilian opportunities and other factors which may generate a behavioral response.

Procedure:

This study assessed alternative approaches to incorporating an econometric module in ODCSPER's redesigned strength management system. It includes an examination of the operation of the strength forecasting system and an assessment of the analytical needs of strength planners. The study also looked at available econometric methodologies and results available in the literature. These findings were integrated with an evaluation of the major management issues for individual Army personnel communities.

Findings:

Structuring the econometric module so that it modifies baseline rate forecasts appears to be most compatible with the cell-based Markov-type of personnel forecasting system planned for continued use by the Army. This implies a two-step rate forecast when the econometric module is applied.

A module that uses the ACOL (annualized cost of leaving) financial incentive variable appears to provide the greatest flexibility. It addresses the "horizon" problem in a rational and consistent way. Though less rigorous and flexible than the DRM (dynamic retention model) for some policy questions, it is much easier to manipulate than the multiple horizon dynamic programming model. Finally, its parameters can be estimated from either the ACOL or ACOL-2 formulation, but applied within the context of the Markov assumptions.

For enlisted personnel, the module must adjust monthly reenlistment rates. Existing research has focused on annual decisions; therefore, in the near term the module must make some adjustments to adapt the annual estimates to monthly forecasts. In the longer term, a monthly retention model for enlisted personnel is important.

Utilization of Findings:

The enlisted element of the econometric module is the most critical, given the size of the enlisted force and the relative impact it has on the Army's personnel budget. Existing models provide annual retention parameters at the all-Army and skill levels for first- and second-term reenlistment behavior. Priority should be given to new research that provides estimates of monthly retention behavior and incorporates new time-series data including the period of the drawdown. MOS-specific or skill-level estimates are necessary as well for SRB planning.

The existing OPICC (Officer Personnel Inventory, Cost, and Compensation) retention model for ACC officers provides adequate parameters for the ACC element of the econometric module. No additional research is warranted presently, although the parameters should be reestimated in the future to incorporate newer historical data, particularly for the full drawdown period.

AMEDD officer branches also require an analytical capability within the econometric module. These officers are subject to well-defined sets of alternative career opportunities and are often costly to recruit and retain. There are no existing Army models of AMEDD officer retention; estimation of a set of models for these branches is a high research priority. The models should vary by specialty within the Medical Corps and the Army Nurse Corps. A Dental Corps model is also needed. Models for remaining AMEDD groups are also needed, but are a lower priority. AMEDD retention models must account for the link between length of commitment and retention bonuses and use information about sector-specific earnings and employment opportunities.

The Warrant Officer element likewise cannot draw upon any existing research for economic parameters. We recommend development of a model or set of models, possibly distinguishing between Aviators and Technicians.

The final two officer communities, JAG Corps and Chaplain Corps, are small, well-managed communities. We do not feel that empirical research is justified for these groups, but the econometric module should contain "placeholder" dimensions for them.

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INTRODUCTION AND PURPOSE

The Office of the Deputy Chief of Staff for Personnel is redesigning its strength management models used for officer and enlisted strength planning. This redesign effort provides the opportunity to add capabilities to the modeling system.

The purpose of this paper is to provide recommendations concerning the design of an econometric module or set of modules for the redesigned strength management models. The econometric elements of the system will provide the capability to adjust forecasts of the voluntary retention of soldiers in response to anticipated changes in military compensation, civilian opportunities and other factors which may generate a behavioral response.

A relatively large literature has arisen regarding how the voluntary retention decisions of military personnel are affected by changes in military pay, bonuses, the state of the civilian economy and other factors. The theory underlying these relationships has been based largely on the economic theory of occupational choice decisions. Models of the relationship between compensation and other factors and the decision to remain in military service have been estimated using econometric methods applied to data on actual retention decisions.[1]

Econometric models of military retention behavior have been used in analyses supporting major policy decisions within the Department of Defense, and by the Services. For example, the President's Commission on an All-Volunteer Force ("Gates Commission") used econometric estimates to plan for the return to an All-Volunteer Force in 1973, and to estimate its budget implications.[2] Similarly, the President's Commission on Military Compensation (PCMC) analyzed proposed changes to the military retirement system using econometric models.[3]

The Navy and Air Force have, in the past, used such models for strength planning and budget preparation.[4] All of the Services have used econometric estimates in the programming and allocation of the Selective Reenlistment Bonus (SRB) program. Finally, oversight organizations outside of the Department of Defense, such as the Office of Management and Budget (OMB) and the Congressional Budget Office (CBO) have used econometric models of military retention behavior in evaluating DoD programs and in developing policy options.

The ability of the existing systems of Army strength planning models to take into account the effects of pay policy, the state of the civilian economy, and other factors on retention and strength projections is quite limited. The military occupational specialty (MOS) level models for

[1] Much of this literature, as it applies to active duty enlisted personnel, is reviewed in Hogan and Black (1991).
[2] See OSD (1970).
[3] In fact, the Annualized Cost of Leaving (ACOL) model, which is discussed below, was developed to help analyze the changes proposed to the military retirement system by the President's Commission on Military Compensation (PCMC).
[4] The Navy has used a version of the ACOL model for strength planning, budget preparation and the evaluation of policy options to improve retention. The Air Force has used similar models for both officer and enlisted strength planning and policy analysis.

the active enlisted force (MOSLS) can project the effects of SRBs on first term enlisted retention rates by MOS, but do not account for more general types of compensation changes or for changes in civilian labor market conditions. Neither the Enlisted Loss Inventory Model (ELIM) nor any of the officer planning models has the ability to project the effect of compensation changes on retention rates and strength at all. This limits the ability of Army strength planners to consider changes in retention behavior induced by changes in economic incentives when planning for and projecting future Army strength. This, in itself, may mean that the Army's strength projections are less accurate than they might otherwise be.

Perhaps more importantly, however, the Army's current personnel planning system lacks the ability to integrate compensation and bonus policy initiatives, the state of the civilian economy, and strength projections into a persuasive, quantitatively solid, plan—one in which strength levels and readiness goals are tied to specific bonus and compensation policy initiatives.

In this paper, we attempt to answer four related questions with regard to an econometric module for the Army's personnel planning:

1. ***What platform or shape should this module take?*** This question concerns the general form of the module itself and, importantly, how the module will interact with the rest of the Army system. We separate the issue of the platform or the nature of the relationship between the module and the rest of the system—how the module effects the retention rates in the system—from the details of the econometric model itself.

2. ***What type of economic model should be incorporated in the module?*** The key issue here is the precise specification of how compensation, and other factors are formulated to affect retention behavior. There are a number of different formulations of this relationship in the literature.

3. ***Where will the behavioral parameters of the econometric models come from?*** The behavioral parameters of the econometric models—the estimates of the precise quantitative relationship between changes in compensation and other factors and changes in voluntary retention—are typically estimated from actual data using econometric or statistical techniques. The choices here include (a) estimates from original econometric research; (b) estimates taken from the existing econometric literature on military retention models directly; and (3) judgment based on the literature.

4. ***Which Army communities would benefit most from an econometric module?*** Adding a behavioral module to a personnel community is costly. The decision should be based on the expected net benefits.

We review alternative econometric models for predicting effects of economic factors on soldier's retention. Based on this review, and on an understanding of the Army personnel planning system, we determine the best methods of incorporating behavioral or econometric retention models into the Army manpower planning system. In this determination, we attempt to consider both the advantages of alternative econometric models and how the alternatives will "fit" within the Army's new system.

Moreover, given that resources are scarce, we determine which Army personnel communities are likely to benefit the most from a behavioral retention module. That is, we provide a prioritized list by personnel community, where the priority is determined by the net benefits to the Army of the capability to incorporate behavioral retention effects in each respective community. Finally, based on our assessment both of econometric methods and models, and Army personnel communities, we develop an explicit plan for incorporating econometric modules into the Army personnel planning system. The plan includes a description of the type of module relevant to each Army community and an assessment of the net benefits of an econometric module for each community.

In the following section of this report, we discuss criteria for the applicability of econometric modules to the Army personnel forecasting system. We then review alternative econometric models applying the criteria to the alternatives. The next section of the report reviews the particular circumstances and needs of each Army community. This information is combined with the information gleaned from the assessment of alternative econometric models in order to provide community-specific assessments of the best econometric model for each community. In the final section of the report, we summarize recommendations regarding the econometric module in general, and specific econometric models for the various Army communities. We also present our assessment of the priorities for an econometric module by Army community.

A design specification report, based on the recommendations of this paper, is included as Appendix A. A research plan for developing the behavioral parameters of the econometric models is at Appendix B. Finally, in Appendix C, the existing empirical literature on military retention is reviewed.

REVIEW AND EVALUATION OF ECONOMETRIC MODELS AND TECHNIQUES

In the first part of this section, we discuss the considerations and criteria for assessing the applicability of alternative econometric models to the Army personnel forecasting system. In the second part, we review alternative models in light of these criteria.

Platform vs. Behavioral Parameters

The econometric module conceptually consists of two parts. The first is the platform for adjusting retention rates in response to economic and other factors. The platform concerns how the module interfaces with the rest of personnel system to affect retention rates and inventory projects. The second part of the module consists of the model and behavioral parameters that provide a quantitative estimate of the responsiveness of retention rates to changes in compensation and other factors. One can put into place the platform or mechanics for adjusting rates, while retaining the flexibility to substitute alternative behavioral parameters—factors that generate the precise retention change in response to a change in economic incentives.

Typically, the behavioral parameters of an econometric retention model are estimated from data on actual retention decisions. Econometric or statistical methods are applied to isolate the relationship between compensation and other factors, and observed retention. The process of estimating such relationships for various Army communities places significant demands on the data, and requires time and analytical resources.

However, the platform can be put in place without, necessarily, the original empirical research necessary to provide the behavioral parameters. Instead, estimates from the existing empirical literature on military retention behavior or judgment, grounded in this empirical literature, can be substituted until original research can provide community-specific contemporary results. The urgency with which additional community-specific original research is required depends upon the availability of existing literature relevant to the particular community, the nature of the policy issues, and how well the model predicts using the best parameter estimates available without the additional applied research.

The platform for the econometric module can be constructed in such a way that substitution of alternative behavioral parameters in the module can be done quickly and easily. In fact, one can incorporate a sensitivity analysis to alternative behavioral parameters as a design feature of the econometric module. The larger point is simply that the design and construction of the econometric module platform can, to a large extent, be separated from the applied econometric research conducted to estimate the parameters of the model. Substitutes (literature estimates, judgment) can be used in the short run.

Criteria for Evaluation of Alternative Econometric Models

We use the following criteria in evaluating alternative econometric models and techniques for application to the Army's personnel inventory projection system.

1. ***Consistency with the underlying economic theory of occupational choice decisions.*** A model that is firmly grounded in an underlying theory of how military members make retention decisions is more likely to serve the Army over the long run better than a purely atheoretical, *ad hoc* model. The economic theory of occupational choice is, we believe, the strongest candidate for serving as this underlying theory. It is the foundation of most of the econometric models currently used by the Services. The advantage of a model that has a solid theoretical foundation, as opposed to one that merely "fits" the data over some historical period, is that the theoretical model offers some recourse when the applied model fails to predict well. One can refer to the deviations between the theoretical model and its empirical application as a starting point for understanding why the model may not predict well. In addition, an applied model that is faithful to an underlying theoretical structure will, generally, be more flexible in its ability to estimate the retention impacts of new policies than an atheoretical model.[5]

2. ***Goodness-of-fit.*** The ability of a model to explain historical variation in retention, as measured by various statistics, is directly related to its ability to predict future retention rates. Because it is an economic model of behavior, the ability to explain and to predict changes in retention as a function of changes in pay, other policy variables, and the state of the civilian economy is most important. Hence, while overall "goodness of fit" measures are important, the statistical significance of key individual variables in the model, such as compensation and the unemployment rate, are also important, given that these variables do affect actual retention behavior.

3. ***Compatibility with Army's personnel system forecasting techniques.*** This is the most important criterion and it has at least two, related, notions associated with it. First, it must be feasible to integrate the econometric module with the Army's system and its techniques. For example, the Army's inventory models, typically, are Markov models in which inventory "cells" are aged over time by transition probabilities. One element of these transition probabilities is voluntary retention rates. The econometric model must be able to operate on these retention rates in a way that is consistent with the transition probability matrix that ages the inventory. This may limit the econometric models that can be considered. Second, "compatibility" in a broader sense includes the ease with which the model can be applied by the Army staff. Hence, a sophisticated model but one which is particularly complicated and cumbersome to use or to maintain would not do

[5] For example, an ad hoc model in which SRBs enter as numerical multiples (level 1, 2, etc.) will not be able to predict the effects of a change from lump sum to installment bonus payments on retention. A theory-based model, where the bonus is integrated with overall compensation, is more likely to be able to predict a difference in retention based on the changed payment scheme.

well in the "compatibility" area even though the model may be feasible in the sense that it can be integrated with the personnel forecasting system.

Compatibility with Army's Forecasting Methods and Techniques

This section is concerned with the limits that the Army's personnel forecasting methods may place on the types of econometric modules that can be considered for the system. That is, it addresses the first, more narrow sense, of "compatibility" introduced in the previous section.

Econometric Module Integration. The econometric module can be integrated into the Army's system in one of three ways. First, the module could produce rates that are part of the baseline forecast rates. That is, the econometric module becomes an integral, required part of the system in that all voluntary retention rate forecasts are produced by the econometric module. The econometric module may account for non-economic as well as economic factors affecting retention. This approach obviates the need for a separate econometric module by building it into the system directly. The shortcoming of this approach is the module cannot be "switched off." It must operate in order for the system to operate.

Second, the econometric module can produce voluntary retention rates that serve as an optional replacement for some baseline set of forecasts produced by the Army's system that take into account, perhaps, non-economic factors affecting retention. This adds a policy analysis capability when needed but retains the option of choosing to consider only the non-economic factors affecting retention that are present in the system's baseline forecasts. Further, by fully replacing the baseline forecast with a completely new forecast of voluntary retention rates from the econometric module—a forecast that includes both economic and non-economic factors— it avoids the potential problem of consistency and "double counting" that may be associated with the third alternative described below. A shortcoming of this method, relative to the method to be described below, is that the difference in inventory forecast when using the "baseline" rates and the rates from the econometric module may reflect differences in the way non-economic factors are considered, and not simply the effects of the economic or behavioral factors.

Third, the econometric module could be constructed so that it makes an adjustment to the baseline rate forecast. Here, there is an explicit division of labor between the baseline retention forecasting technique and the econometric module. The baseline method adjusts rates for (some) non-economic or non-behavioral parameters affecting retention, including, perhaps, demographic factors. Then, at the option of the Army staff, the econometric module further adjusts rates for the effects of pay, unemployment rates, and so forth. Clearly, this poses some limitations on the nature of adjustments. It assumes that economic and non-economic effects on retention are additively or proportionally separable (e.g., there are no "interaction" effects between economic and non-economic factors).[6] If the econometric module developed is coordinated with the development of the baseline forecast, this method, which adjusts the baseline rates to reflect the

[6] Moreover, even though the econometric module will adjust only for economic or behavioral factors, it is important that non-economic factors are included in the estimation of the behavioral effects to obtain unbiased parameters.

economic and policy factors, will produce consistent forecasts which one can use to directly compare forecasts with and without economic and policy adjustments considered.

In addition, there are types of econometric models that consider the past retention behavior of a cohort of soldiers when predicting future retention. These "path-dependent" models consider dynamic "selection" and its effects on future retention. They predict, for example, that if unusually large numbers of soldiers in a cohort or year group are induced to stay in one period, the subsequent period's retention rate for that cohort is likely to be lower than average. However, to apply the dynamic selection feature to retention data, the models require the entire retention history of the cohorts of soldiers for which they are going to predict future retention. Not all personnel inventory projection methods are compatible with this requirement.

Inventory Forecasting Methods and Implications for the Econometric Module

The most appropriate way to integrate the econometric module will, of course, depend on the methods by which the Army's system will forecast future inventories. There are (at least) three potential approaches to inventory projection:

1. Entity simulation
2. Cell-based Markov
3. Cohort projections (survival analysis)

In an entity simulation model, soldiers transition from one state to another based on Monte Carlo simulation. A "state" is the description of the soldier's status. It would typically include, at least, year of service, rank or paygrade, and military occupational specialty. Other "states" might include states that exit the system, such as "civilian" and "retirement". During each period of the simulation the soldier implicitly draws from a distribution representing underlying transition probabilities. Several "draws" may reflect a compound set of events, such as retention and promotion. Changes in retention or loss rates, promotions rates, and so forth are reflected in shifts in the parameters of the underlying distributions of the Monte Carlo simulation. The forecast becomes the mean of a large number of simulations. The process of generating the forecast naturally produces a distribution around the mean that provides an indication of the uncertainty surrounding the projection.

The econometric module, then, will operate to shift the mean of the distribution of voluntary retention rates, as a function of compensation, the state of the civilian economy, and other factors. The underlying distribution can be independent of the past (a Markov assumption) or may depend on past retention behavior (a "path dependence" assumption.) Currently, the Army has no major personnel inventory forecasting model that uses entity-level simulation and Monte Carlo methods. However, such models are being used in the Air Force.[7]

[7]In particular, the Air Force has a PC-based entity simulation model that is used to model its PCS move process.

A cell-based Markov model is the most common structure of inventory projection model. Variations are used by all of the Services to project personnel inventories. The Markov model uses sets of transition probabilities to describe movement of inventory from one cell or state to another over time. These probabilities may include estimates of voluntary retention rates, involuntary "attrition" rates, promotion rates and so forth. A transition probability matrix describes all possible movements between cells. A key assumption of a Markov model is that the current state or cell provides all the information necessary to determine the transition probabilities to other states or cells. The path or history of how particular soldiers get to that cell is not relevant. In that sense, it is "path independent."

The Army's major enlisted personnel inventory projection model, ELIM, is a cell-based Markov model, and it is likely that the new system will also be grounded in the same methods. The versatility and simplicity of the method has much to recommend it. The econometric model can operate either on the baseline rate projection, adjusting voluntary rates for economic and other behavioral factors affecting retention, or can serve as a replacement for the baseline rates. It is not as easy to provide confidence intervals or other measures of uncertainty in the Markov approach as it is in the Monte Carlo simulation method.

The Markov model assumption does place some limits on the type of econometric module that is relevant. In particular, in some types of economic models of retention, the probability that the soldier chooses to reenlist is not independent of the path taken to the reenlistment point. In particular, if the retention rates for that soldier's cohort up to that point is greater than is typical, some models may predict that the current or "spot" reenlistment rate will be lower than might otherwise be expected. For example, perhaps an especially lucrative reenlistment bonus at the previous reenlistment point induced significant numbers of soldiers, who otherwise might have left, to stay for at least one more term. If so, we can expect that large numbers of those induced to stay will leave at the current reenlistment point. Some econometric models explicitly take this past behavior into account in predicting future rates. Such a feature is difficult to apply in a system where the underlying method for projection is a cell-based Markov model.

"Cohort models" project future retention based on the cohort's history as well as current conditions. This type of model captures the "path dependence" aspect of retention behavior—the fact that a cohort with abnormally high (or low) retention up to the current period is, other things being equal, likely to experience unusually low (or high) retention in future periods.

A simple, but extreme, example of this dependence is the effect of a "stop loss" order on future retention rates. A large portion of the soldiers who otherwise would have left the Army during the period of the stop loss will leave when the order is relaxed. A cohort model may provide the opportunity to predict the low retention rate that would occur at that point. A Markov type of model would not.[8]

[8] A second example is a cohort that enjoyed an especially generous first term reenlistment bonus, inducing a large number of soldiers who otherwise would have left at the first term point to reenlist.

A cohort model requires panel or longitudinal data that contains the entire retention history of a year group to predict future retention. The econometric module of a cohort model could, potentially, capture the "path dependence" effect in predicting future retention rates. The econometric model, itself, would require panel data to estimate and would also require a cohort's entire history to predict future retention rates. The econometric module's projected rates would replace the baseline rates in a cohort model projection.

A cohort model, however, is not well suited for the types of inventory projections that the Army makes over the period of the Program Objective Memoranda (POM). A typical analysis begins with the personnel inventory inherited from the previous period. This is a mixture of cohorts ranging from those with less than a year of Army service to those with more than twenty years of services. A "cohort" model, in the sense we have defined it, would be a cumbersome method of predicting retention of this inventory over the next year or several years.[9]

It is highly likely that a cell-based Markov model will be the foundation of Army's redesigned system. Econometric methods which take retention history into account in predicting future retention—i.e., the panel data models that account for cohort selection—will be difficult to apply to their full potential in the system.

Projection Period and Frequency

A projection or forecast period that encompasses at least the seven year period of the Program Objective Memoranda (POM) is typically required by most Department of Defense personnel forecasting systems. In addition, the Services are required to remain within an annual end strength constraint. They must also ensure that personnel expenditures (pay, allowances) remain at or below Congressionally authorized amounts over the fiscal year in which the budget is actually executed.[10] For this reason, the Army and the other Services monitor actual strength levels on a monthly basis as the budget is executed. Moreover, they require that most of their forecasting models project monthly. ELIM, for example, projects on a monthly basis. Its replacement system will also require monthly projections.

An underlying personnel system that forecasts monthly has implications for the econometric module. Most econometric models of military retention behavior are estimated using annual data. In fact, some estimation problems increase when the time period or window of observation for retention decisions narrows.[11] To be compatible with a monthly forecasting model, the

[9] Perhaps a better use of a "cohort" model is to predict the long-run or steady-state effects of major changes to the personnel and/or compensation system. Retirement reform proposals, permanent changes in initial ETS and so forth can be usefully analyzed with a cohort model.

[10] Over-expending the MP,A account is at least a technical violation of the Anti-Deficiency Act.

[11] First, with a monthly estimation interval, the seasonality of military pay raises may make it seem that the real value of military pay is greater after the October (or January) pay raise, and then declines throughout the fiscal year. It would be a mistake to include this source of real pay variation in the model, because soldiers fully anticipate this seasonality in their decisions. Hence, a good model will eliminate this seasonal variation in pay in estimation. Failure to do so will bias the pay coefficient toward zero. Second, soldiers who choose to reenlist will typically do so before the actual month of their ETS. Those who are leaving will not leave until the month of their ETS. This

econometric module must either itself be monthly, or be capable of translating annual retention rate forecasts into the implications for monthly rates.

A particular problem may arise in forecasting monthly enlisted voluntary retention rates from an econometric model estimated using annual data because of the fixed contract obligations of soldiers. Soldiers reenlist for finite periods. During the period of the reenlistment obligation, soldiers typically are not free to leave voluntarily. At the end of an obligation—an ETS—the soldier may generally choose to leave or to reenlist for another term. If all soldiers were to reenlist only in the month of their ETS, fixed obligations themselves would not present significant problems in forecasting monthly reenlistment rates using an econometric model estimated from annual data. However, soldiers may choose to reenlist early—that is, they may reenlist in months prior to the month of their ETS. This presents some difficulties for an econometric model estimated using annual data.

An econometric model that is estimated using annual data can forecast a monthly voluntary retention rate accurately, except for (a) the phenomenon of early reenlistments; and (b) seasonality in reenlistment. If reenlistments only occur in the month in which soldiers are at their ETS, there is very little difference between an annual retention model and a monthly model. If, on the other hand, significant numbers of soldiers reenlist more than a month prior to their ETS and, especially, if variations in economic factors induce variations in the number or proportion of early reenlistments, an annual econometric model will not be able to predict this component of the monthly variation in rates. Moreover, an annual model will not be able to account for consistent variation in reenlistment rates by month of the year (i.e., seasonality). However, if there is no seasonality in reenlistments and almost all soldiers reenlist in the month of their ETS, an annual model can predict monthly rates as well as it can annual rates.[12]

If there is seasonality in monthly reenlistment rates, the "baseline" rate forecasting model should capture this variation. Then, the econometric module can operate on these baseline rates, which already reflect seasonality, to adjust them for changes in economic factors. If early reenlistments are an important phenomenon, and the proportion reenlisting early is responsive to economic factors, a monthly econometric model should be estimated. For example, the ability to predict changes in early reenlistments in response to anticipated within year changes in selective reenlistment bonus multiples would require an econometric model estimated using monthly data. However, if the total number of reenlistments over the fiscal year is important, and the assumption that actual reenlistments by month are proportional to the number at ETS each month

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means that, if the soldiers "decisions" are modeled as if they are made at the time of either reenlistment or leaving, those leaving will appear to have greater military pay, on average, than those reenlisting. If not corrected, this will bias the estimated pay coefficient. Finally, if there is seasonality in the distribution of ETS dates, and there undoubtedly is for first ETS point due to seasonality in accessions, and if those who reenlist do so early, there will be induced seasonal variation in monthly reenlistment rates that has little to do with career choices. All of these problems are eliminated or mitigated by using annual data rather than monthly in the estimation of the econometric model.

[12] Assume the econometric module predicts an "annual" reenlistment rate for those at ETS during the year of 60%. Then, applying this same rate each month to those soldiers who are at ETS during the month will produce the same total reenlistments, distributed across months in proportion to the ETS distribution.

is adequate for budget and policy purposes, econometric modules based on annual data should be satisfactory.

In the officer force, officers generally are not encumbered by fixed obligations.[13] They implicitly make continuous decisions to stay or leave. To convert an annual rate that applies to all officers in a given grade and year of service in an annual period to a rate that applies to these officers each month is relatively straightforward.[14]

The reenlistment window for enlisted personnel currently ranges from twelve months before ETS until three months before ETS. Monthly tracking of reenlistments is important for budgetary reasons. An annual reenlistment model will not provide accurate monthly estimates to the extent that seasonality in ETS dates and economic factors affect timing of reenlistments within a fiscal year. Seasonality ought to be accounted for already in the rates forecast by the strength planning system. However, timing of pay raises and changes in external economic conditions may affect reenlistment patterns as well. Because of these economic effects, we recommend estimating econometric models of retention behavior at some point using monthly data. Until such results are available, estimates from annual models can be applied to monthly data, with appropriate adjustments, that can approximate the correct monthly adjustment.

Army Personnel System Dimensions

The dimensions of the underlying Army system will affect the econometric module in several ways. Four particular dimensions of the underlying personnel forecasting system may affect the type of econometric module chosen:

- ***ETS dimension.*** Some forms of econometric models consider not simply the stay/leave (or reenlist/leave) decision, but also whether the soldier may decide to extend his or her current reenlistment, reenlist or leave. The model may even include various lengths of reenlistments as options. A necessary condition for those types of models to be useful is that the Army personnel forecasting system has a dimension that accounts for time to ETS, and that short term extensions are an important option in the overall stay-leave decision. If so, it may be important to distinguish between a short term extension, which moves the soldier's ETS date only two years or less into the future, from a reenlistment, which increases the ETS by between three and six years. While there is, in fact, an ETS dimension, short term extensions are executed largely for reasons unrelated to the retention decision.[15] Because short term

[13] They do incur obligations in return for some Army sponsored education and training. These obligations, if known, will not present the same problems as the early reenlistments. Officers simply will not be considered to be making retention decisions while under an obligation. Once the obligation has been satisfied, the officers are assumed to be making continuous decisions.

[14] Moving from annual to monthly rates, however, is analogous to increasing the "compounding" interval. Hence, if the loss rate is 12% annual, it will be about 1% monthly. However, computed total losses over the year will be slightly different in the annual and monthly models because of the change in intervals over which losses are evaluated.

[15] For example, a short term extension of the ETS point is often required to ensure that the time remaining on an enlistment coincides with the time required to complete a new assignment.

extensions are not an important option in the retention decision, such a capability in the enlistment module is not likely to be important. Moreover, the ETS distribution is updated based on actual decisions made by those who reenlist, shortly after the decisions are made. Hence, the ability to predict length of reenlistment is not important for short term strength management decisions.[16]

- ***Grade/YOS dimensions.*** Similarly, the underlying personnel model may account for retention rates that vary by grade as well as year of service (YOS). If so, an econometric model that permits predicted retention rates to vary by grade as well as year of service may be particularly useful. Note that if the only effect of grade is to shift the underlying retention rate, this can be done in the baseline rates. A grade dimension in the econometric model is more interesting if, for example, the responsiveness of retention rates to pay and other incentives varies by grade. If the Army system does not have a grade dimension, but the econometric module does, the grade dimension in the econometric module can be "integrated out" by taking a weighted average of the by grade rates at each year of service. Alternatively, if the system does allow retention rates to vary by both grade and YOS, an econometric model that does not have a grade dimension can only predict rates at the average grade for a given year of service.

- ***Demographic characteristics of the soldier.*** Again, an econometric module that permits rate predictions by the demographic characteristics of soldiers (sex, minority status, education, and marital status) is more interesting if these characteristics affect the responsiveness of soldiers to incentives, and not simply level changes in rates. However, to be most useful to the Army, the Army personnel forecasting system should have separate dimensions for these categories in its inventory projections.[17]

Compatibility in dimensions between the econometric module and the underlying forecasting system is a necessary condition for the particular econometric model's feature to be useful to the Army. However, simply because it is feasible does not mean that the econometric feature should be included. The importance of the policy issues at stake and the difference the respective model's features may make in assessing the policy issues should ultimately determine if the features should be included.

<u>Alternative Econometric Models</u>

For the purposes of discussion, we can categorize alternative econometric modeling approaches into five broad generic types:

[16] The ability to predict reenlistment lengths may still be important for budgeting for Selective Reenlistment Bonuses and for predicting the ETS distribution for future reenlistments that, themselves, must be predicted. However, this capability appears to be of secondary importance to the Army at this time.

[17] If the econometric module itself can track a changing demographic mix and its effect on reenlistment rates, the rate forecast in the Army System can be improved even if the Army's forecasting system does not include demographic dimensions.

1. **Non-structural (ad hoc) models.** These include models with little or no underlying theory, with explanatory variables included largely on the basis of statistical fit over a historical period.

2. **Single-choice path-independent structural models**. These models focus on the stay (or reenlistment) -leave decision and are solidly based on an underlying theory of job choice.

3. **Single choice path dependent structural models**. These models also focus on the stay-leave decision and are solidly based on theory. In addition, this class of models attempts to account for dynamic selection—the tendency for past attrition to affect future retention rates of a cohort of soldiers.

4. **Other hazard models**. A hazard model is a generic name for a model that predicts the incidence, or probability, of an event, such as leaving the military, as a function of time and other factors. The previous two categories of models are also in the general class of hazard models. This general category includes the remaining hazard models that are not, perhaps, as well grounded in occupational choice theory as the previous two categories.

5. **Multiple-option models.** This class of model expands the choice set beyond the stay-leave decision to include multiple options, such as leave, reenlist, and extend; or leave, reenlist for 3, 4, 5, or 6 years.

Non-Structural (Ad Hoc) Models

These models relate retention decisions (stay/leave) to a plethora of economic and non-economic variables, but with little guidance from theory. Statistical fit over a particular historical period is the primary criterion for choosing a model. The major weakness of such models is that, since the specification is unrelated to theory, they are difficult to apply when the forms of compensation change. Equivalently, when a new form of compensation is offered, the models are not likely to be able to predict retention effects. Finally, these ad hoc models address some aspects of military compensation in an arbitrary way. For example, most have no theory of the "horizon" over which military and civilian earnings opportunities should be compared. Instead, they will arbitrarily measure compensation as the ratio of current military pay to current civilian earnings opportunities, or as the present values of military and civilian pay over arbitrary horizons.

One important illustration of the shortcomings of ad hoc model specification is estimates of the effect of reenlistment bonuses. Many models specify selective reenlistment bonuses as dummy variables. Such a specification may predict reasonably as long as the real value of the bonus, as represented by the dummy variable, remains approximately constant over time. However, such a model is incapable of predicting changes in effects when, for example, the value of the bonus erodes because of inflation or when there is a change in the method of paying the bonus (such as a change from lump-sum to installment payments). A structural model, on the other hand, incorporates the bonus into a more general measure of compensation. When the value of the bonus changes, this is reflected in the more general measure of compensation the model uses to predict a change in retention. The econometric model the Army currently uses to predict the retention effects of reenlistment bonuses is an ad hoc, non-structural model.[18]

On the other hand, ad hoc models tend to be relatively easier and, perhaps, less costly to estimate than theoretically grounded structural models. Their shelf life will be less, however, and they will be less flexible. Moreover, when prediction errors tend to grow, there is no theoretical foundation to suggest avenues for improvement in the models, since they are based solely or largely on historical fit of the data.

To summarize, the benefits of using ad hoc models include:

1. They are relatively inexpensive to estimate and reestimate.
2. They can predict the effects of specialized elements of compensation reasonably well as long as the world does not change "too much" over time.
3. Most can be readily integrated with the overall inventory projection system.

Major weaknesses include:

1. They are inflexible in policy analysis in that they cannot project the effects of new forms of compensation.
2. They quickly become obsolete when the underlying compensation structure changes.
3. They offer little rationale for the predictions other than the historical fit of the model.
4. When prediction errors become unacceptably high, the atheoretical models offer no insights regarding the poor performance and no suggestions regarding where to seek improvement.

Single Choice Path Dependent Structural Models

These econometric models attempt to specify empirical relationships in ways that are consistent with an underlying theory of retention behavior. Typically, the theory will be related to the economic theory of occupational or job choice decisions. The models are limited to a single decision—stay or leave. Moreover, the decision is assumed to be a function only of current and expected future values of variables. There is no attempt to account for past retention and the effects past retention may have on future retention through the selection of soldiers surviving to the current decision.[19]

The most prominent model in this category is the Annualized Cost of Leaving (ACOL) model. Indeed, a version of the ACOL model is, or has been used, by all of the Services and by the Office of the Secretary of Defense, the Office of Management and Budget, and the Congressional Budget Office to predict the retention and inventory effects of changes in compensation.

[18] The model is the SRB model that is used with the MOS level inventory projection model, MOSLS.
[19] That is, these models do not account for unobserved heterogeneity in a systematic way.

The Annualized Cost of Leaving (ACOL) model was originally formulated by Gary Nelson and John Warner to analyze the retirement reform proposal of the President's Commission on Military Compensation (PCMC).[20] The salient problem to which the ACOL model provided a non-arbitrary solution was the "horizon" over which one compares military and civilian pay to predict the retention effects of changes. The issue of the "horizon" is particularly importantly in the military because of its retirement system, which is vested only after completing twenty years of service. Hence, whether a change in the retirement system affects retention at, for example, the first or second term reenlistment point depends on whether the "horizon" over which one compares military and civilian pay extends to the twenty year point, or extends only through, for example, the end of the next reenlistment term.

The "ACOL" solution to the horizon problem is to choose the horizon for which the annualized, or annuitized, difference between military and civilian pay is the greatest. In the literature, this is sometimes called a "maximum regret" solution. This solution can be derived from a simple model in which one postulates a fixed "taste for service" for a given soldier. This dollar-denominated "taste for service" variable—which we can denote as γ_I—can be positive or negative, but it is incurred by the individual each year that the individual remains in service.

The simple decision rule is: stay at least one more term if the net financial benefits to staying (military pay less civilian pay) plus the dollar value of the non-pecuniary aspects of service (the "taste" for service) exceed zero. Now, define ACOL(h) as the annualized difference between military and civilian pay, calculated over a horizon, h.[21]

That is, ACOL(h) is calculated under the assumption that the individual's decision is to remain in service for h more periods, enjoying military pay over those periods, or leave immediately and receive civilian pay over those periods. The horizon chosen to analyze the retention decision, h*, is that horizon h for which ACOL(h) is the greatest. Hence, if at the second term reenlistment decision, ACOL is greatest if the horizon extends only over the period of the reenlistment (typically four years), the ACOL(h*) will be calculated over a single term horizon. If, however, ACOL(h) is greatest if it includes the present value of the military retirement annuity in the calculation, the optimal horizon is likely to be that which takes the soldier to twenty years of service, the vesting point for military retirement.[22]

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[20] See Enns, Nelson, and Warner (1984).

[21] Let PV(h) be the present value of the difference between military and civilian pay, calculated over horizon h:

$$PV(h) = \sum_{t=1}^{h} (M_t - C_t)/(1+r)^t$$

where M_t and C_t are military and civilian at period t, where t indexes time after the decision point, and r is the discount rate. Then, ACOL(h)=PV(h)D(r,h), where D(.) is the "annuity factor" given the horizon h and discount rate r, that turns the present value of the difference into a constant annual amount over horizon h, ACOL(h), that has a present value at the decision point of PV(h).

[22] If, at the optimal leaving point, retirement is vested, PV(h) is modified to include the present value of the retirement annuity:

$$PV(h) = \sum_{t=1}^{h} (M_t - C_t)/(1+r)^t + \sum_{t=h}^{T} A_{h+i}/(1+r)^t$$

The retention decision rule, then, is stay (at least one more period) if:

$$ACOL(h^*) > -\gamma_i,$$

The ACOL model has been estimated using probit or logit functional forms. Research using the ACOL model has been conducted from the late 1970's to the present. There are empirical results available in the literature for the enlisted forces of all the Services, for selected occupational groups within the enlisted force, and for many officer communities.

Somewhat more recently, a variation of the simple ACOL model sometimes referred to as a "stages" model has been developed and applied. In this variant, separate, independently estimated ACOL models are estimated for various tenure ranges or "stages" of a military career. The advantage of this approach, over that of the simple ACOL model, is that by allowing separate coefficients to be estimated over different parts of the career, potential biases from failure to account for selection effects may be reduced. That is, "average" selection can be accounted for by separate intercept and parameter estimates over various "stages" of a military career. However, this pragmatic, ad hoc adjustment is not well grounded in theory and will not fully account for selection effects.

The strengths associated with a simple ACOL model approach to the Army's econometric module include:

1. It provides a consistent structure for evaluating most types of compensation changes.
2. It solves the "horizon" problem in a reasonable, non-arbitrary way.
3. It can be used to analyze many new forms of pay and changes in the structure of compensation without requiring reestimation.
4. It has a track record of being reasonably accurate and flexible in analyzing the most common types of compensation changes. There is a significant empirical literature from which to draw.
5. The ACOL model, in particular, is relatively straightforward to implement, is generally compatible with most inventory projection models, and has gained a degree of acceptance in the applied research and policy communities.

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where A_{h+i} is the military retirement annuity that the soldier begins collecting in period h, and continues to collect until death at T (with time again indexed to the decision point. Note that the entire present value of retirement is "annuitized" over the horizon h, even though the retirement annuity itself extends to T. The reason is that the annuity becomes "earned" or is vested at h, and is therefore part of the financial benefit of staying at least h more periods rather than leaving immediately.

Major weaknesses include:

1. It is a single horizon, "maximum regret" model. Compensation changes beyond the horizon have no effect on retention. As a result of this feature, it may not be able to capture the effects of some types of compensation changes.[23]

2. The "path independence" assumption—the feature that the ACOL model considers only current and future factors and not the past in predicting retention—implies that it will not account for the retention rate implications of unobserved heterogeneity and selection.[24] On the other hand, however, this is the Markov modeling assumption that underlies the Army's system.

Path Dependent ("Panel") Structural Models

In response to some of the theoretical shortcomings of the simple Annualized Cost of Leaving model, a class of retention model that explicitly accounts for dynamic selection has been developed. These models are also structural models based on a solid theoretical foundation and, in fact, tend to be more consistent with theory than the path independent models. Unlike the path independent models, current retention is a function of current, expected future, *and past variables* that influence the decision to stay in service.

Recall that the potential problem is that members choose to remain in or leave military service over time in part based on unobserved factors. These factors, which will include how well they like military life, are not observed directly by the researcher. Hence, the literature refers to these "taste" factors as unobserved heterogeneity or unmeasured differences among members of a cohort or panel. As a cohort progresses through a military career, the distribution of these unobserved factors changes. Those with relatively low "tastes" for military life are more likely to leave. Hence, the average "taste" for service tends to rise for a surviving cohort over time due to this dynamic self-selection. This selection process will affect future retention rates. If the selection process remained about the same over time across cohorts, models that did not take into account the selection process, such as the simple ACOL model, would predict well. However, if the selection itself changes over time, a model that takes dynamic selection into account should predict better than one that does not.

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[23] In addition, a literal application of the ACOL model generates a clearly false prediction. The literal prediction is that, for a given cohort, if a future ACOL is greater than any ACOL value in the past for that cohort, the voluntary retention rate should be unity. This is because, at the earlier, lower ACOL value, all those for which $ACOL(h^*) < -\gamma_i$ will have left. For all of the remainder, $ACOL > -\gamma_i$. If the future ACOL value is greater than any ACOL value at a past decision point for that cohort the retention rate should be 100 percent. This implies that, as ACOL values rise as the 20 year retirement point is reached, voluntary retention rates should be unity. While they are very high, retention rates are not 100 percent.

[24] Recall that this "selection" issue is that future retention rates should be conditioned on the underlying "taste" distribution or the distribution of unmeasured factors of the surviving cohort. The "path independent" models do not do this.

An example in which dynamic selection may make a difference is the payment of an unusually large first term reenlistment bonus to a particular Army cohort. This bonus will induce some soldiers who would have otherwise left the Army to reenlist. When this cohort arrives at the second reenlistment decision point, its average "taste" for service will be less than the average for the typical cohort because of the inducement of the bonus. Other things being equal, the second term reenlistment rate will be lower than it otherwise would be. A model which accounts for this dynamic selection will, in principle, be able to predict this reduction in the second term reenlistment rate while the "path independent" models will not.

Two models that account for dynamic selection have been developed and applied to military retention: the ACOL-2 model and the Dynamic Retention Model (DRM). The ACOL-2 model, originally developed by Black, Moffitt and Warner (1990) incorporates the "ACOL" variable in the same way as the simple ACOL model. Hence, it remains a single horizon, maximum regret model. However, the error structure in the ACOL-2 model is a two-factor variance component model. The error consists of an individual-specific component that is fixed over time—the "taste" factor—and a random component that is independently distributed over time with mean zero. Hence, the decision rule in the ACOL-2 model is: reenlist at decision point t if

$$ACOL_t(h^*) + \gamma_i + \varepsilon_{i,t} > 0$$

where γ_i is an individual-specific taste parameter that is constant over time and $\varepsilon_{i,t}$ is a random component with mean zero and is independently distributed over time. That is, the individual draws a new ε_i at each retention decision point, but keeps the same γ_i at each decision.

The ACOL-2 model is estimated as a panel probit.[25] Panel data—repeated observations on the same individuals across several decision points—is required to estimate the model. The correlation in the error over time allows one to account for dynamic selection and to predict the consequences for future retention.

The Dynamic Retention Model (DRM) was originally developed by Glenn Gotz and John McCall of the Rand Corporation.[26] It is similar to the ACOL-2 model in that it formulates its error structure as a two-factor variance components model. Hence, it accounts for dynamic selection in much the same way that the ACOL-2 model does. However, it differs from ACOL and ACOL-2 in the way it calculates the financial incentive to stay.

Instead of solving for the single horizon which maximizes the net financial benefit of staying (as does the ACOL and ACOL-2), the DRM's financial variable is a weighted average of the financial incentive to stay over all possible horizons. The "weights," however, are endogenously determined and are, in fact, the probabilities of leaving at the horizon, conditional upon having remained in service up to that point. Because of this relationship, the model is solved as a dynamic programming model. One first solves for the retention probability at the last retention decision point, conditional upon having survived to that point. Then, this probability is used to

[25] See, for example, Black, Hogan and Sylwester (1987).
[26] Gotz and McCall (1984).

construct the financial incentive to stay at the next to last retention point. This "backward" solution technique is applied until the initial decision point is reached.

The multiple horizon DRM is theoretically more appealing in that it recognizes that there is some probability that the soldier may leave at each possible horizon. Because it includes compensation beyond the single "optimal" horizon of the ACOL formulation, it provides more plausible predictions of retention effects for some types of pay changes. For example, it will predict a change in retention behavior if the retirement system were to change, even if the "optimal" horizon as defined by the ACOL method did not extend to the retirement point. Further, because it explicitly considers uncertainty in the horizon and the "option" value of leaving at future points, it can predict retention effects for changes in required or obligated service, whereas the simple ACOL model cannot unless the service requirement affects the "optimal" horizon.

However, in many general types of pay changes—across the board pay raises, changes in reenlistment bonuses, and so forth, the DRM's predictions will be very close to those of the ACOL model. Moreover, its historical "fit" of actual retention behavior is very close to that of the ACOL model.[27] Recent advances by Daula and Moffitt (1995) have made a dynamic retention model of military retention behavior more tractable than in the past and, perhaps, have made its application to policy analysis easier. However, it remains the most complex of the models of military retention behavior to estimate and to apply.

The major advantages of the ACOL-2 model include:

1. It accounts for dynamic selection.
2. Its estimates are more efficient, in the statistical sense, than those of the path-independent models of retention.
3. It retains the ACOL variable as the measure of the financial incentive to stay, which is relatively easy to calculate.
4. There is a relatively large applied literature using the ACOL-2 methods from which parameter estimates can be drawn.

Weaknesses include:

1. It requires panel data to estimate.
2. It requires a cohort's or year group's retention history to simulate in an inventory projection model, if the dynamic selection aspect of the model is used. This is not likely to be available in the typical applications of inventory projection models. However, the estimates from an ACOL-2 model are more efficient and perhaps more consistent than those from a simple ACOL model. The ACOL-2 parameter estimates can be used in an econometric module even if the dynamic selection aspects are not.
3. The model is still a single horizon model, which limits its usefulness in analyzing some types of compensation changes.

[27] See Daula and Moffitt (1995).

The strengths of the DRM include:

1. It is a multiple horizon model. Its more sophisticated calculation of the financial incentive to stay can take into account certain types of compensation structures in a way that is more consistent with theory than can the simple ACOL variable.
2. It explicitly accounts for uncertainty in the horizon. It can, in principle, predict retention effects from increases in required service, for example, in cases where the ACOL model predicts no change.
3. Accounts for selection in a way similar to ACOL-2.
4. It is the most sophisticated model in the sense that it is the most consistent with theory.

The weaknesses of the DRM include:

1. It is difficult to estimate and apply. It requires panel data and the calculation of the financial incentive to stay requires a solution to a dynamic programming model.
2. It is particularly difficult to apply as an independent module to a strength forecasting system. As with ACOL-2, however, parameters of the model can be used in the econometric module.
3. It has a particularly poor track record in applications.[28]

Other Proportional Hazard Models

There are a number of related models that specify the incidence of a particular event such as the voluntary retention decision as a function of time in the personnel system and other factors. These may be termed "hazard" models in that they estimate the probability of an event (the "hazard") as a function of some measure of duration. The functional forms used in hazard models constrain forecasts to be in the form of rates or probabilities. The particular functional form will describe how the underlying hazard rate will change as a function of duration or time. In addition, the models will also include variables such as pay and the civilian unemployment rate that shift the underlying hazard rate.

The panel models discussed in the previous section are forms of hazard models. Some of these models may include "path dependency"—explicitly accounting for selection due to unobserved differences in the "tastes" of soldiers for military life—and require cohort histories (panel data) to estimate and to apply.

Hazard models may include non-economic as well as economic variables that affect the underlying retention rate. If so, care should be exercised in using the model in the econometric

[28] The original DRM was constructed as an officer model for the Air Force by the Rand Corporation. Air Force analysts found the model too difficult to understand, and too complicated to run. It was never used for policy analysis. An effort to estimate a DRM for the Navy was never completed because of research problems. More recently, Daula and Moffit (1995) have successfully estimated a DRM for Army enlisted personnel and claim that is tractable to be used by the Army for policy purposes. This assertion, however, has not yet been tested.

module to avoid redundancies with the baseline projections of the Army system. Inclusion of both economic and non-economic factors in a complicated functional form may mean that the model can be applied only as a replacement to the baseline retention rate forecast.

In general, hazard models are a statistically sound way to predict voluntary loss rates. Moreover, they can be specified in a way that is consistent with underlying economic theory. Theory, however, provides little insight in determining precisely which hazard function will fit the data best. For this reason, it may be useful to explore a variety of hazard models to determine the best forms for the econometric modules.

Multinomial Models

The models discussed thus far are limited to predicting one of two outcomes: stay or leave. There may be instances where predictions of multiple outcomes are useful. For example, in the enlisted force, a soldier may choose to leave, to reenlist for between three and six years of additional service, or to extend his or her current reenlistment from several months up to two years. For force planning purposes, it may be useful to estimate how many stayers have committed to a reenlistment and how many have executed short term extensions to a current reenlistment.

There are several types of models in the literature that can be estimated in the multiple outcome case and used to predict probabilities of each outcome. These include a multinomial logit or probit, a sequential logit or a nested logit. They all have the property that, if estimated correctly, the sum of the predicted rates or probabilities is equal to one. Moreover, some forms of multinomial models can be rigorously derived from underlying theory.[29]

A model which distinguishes reenlistments from extensions as well as from losses may be particularly important in developing reenlistment bonus plans (along with budget estimates) at the MOS level. Indeed, the decision to reenlist, rather than to extend, may be very sensitive to the SRB offered. It is important, for budget and SRB estimates, to capture this effect. Such a multinomial model may be less useful in more aggregated enlisted models, where bonus effects can be estimated, at best, only as an average effect across all MOS.

In practice, however, extensions are not a major factor in the reenlistment decision. In the Army, extensions are primarily executed so that assignment lengths coincide with the soldiers' ETS point. Extensions are not a significant alternative to the basic reenlist-leave decision.

Strengths of the multinomial approach include:

1. It permits systematic analysis of policy choices that are not possible in a single alternative model. For example, reenlist and extend can be included in the "stay" options, one can

[29] In fact, the random utility version of the conditional logit model, which is commonly used, can be directly derived from occupational choice theory. For an ongoing Navy project, we have successfully estimated three-choice models for enlisted personnel using both conditional logit and multinomial probit specifications. See Mackin, et. al. (1997).

extend the "leave" options to include enlistment in the reserves, and one could, in principle, include various lengths of reenlistments (3,4,5 or 6 years) as separate stay-related decisions.

2. There is some literature, applied to military retention decisions, available for these models. From this literature, one could obtain policy-related parameters to apply in an econometric module that includes multiple options.

Weaknesses of the multinomial approach to the econometric module include:

1. It requires a manpower forecasting system that is compatible with the range of options included in the multinomial model. For example, if the econometric module predicts extension rates, this is useful only if the manpower system separately accounts for extensions.
2. Such models, while attractive in principle, tend to be less stable than models which include only broadly defined alternatives, such as "stay or leave." In general, the more narrowly the alternatives are defined, the greater are the demands made on the data used to identify, statistically, the parameters associated with each choice.
3. The models are somewhat more complicated to apply than the two-alternative models. This additional complexity is worth its price only if the policies and policy decisions associated with multiple options are important for the Army.
4. Finally, the most important application of a multinomial model has been the inclusion of the option to extend along with the option to reenlist and to leave. In the case of the Army, this is not of practical important. Extensions are executed for institutional reasons rather than as a response to economic conditions.

Summary of the Assessment Regarding Modeling Approach

Table 1 summarizes the role of an econometric module in accounting for various transactions in the strength forecast.

Table 1
Recommendations for Econometric Module by Transaction Type

Transaction	Specific transaction	Role of Econometric Module	Types of Econ. Model	Model Recommendation	Recommended for Army System
Loss					
	involuntary separation	none			
	non-ETS losses (attrition)	none			
	ETS losses	adjust for economic/other factors affecting voluntary retention decisions	ACOL, ACOL-2, DRM	ACOL	Yes Eventually, econometric model should be reestimated using monthly data.
	Non-disability retirement	adjust for economic factors affecting retirement decisions	ACOL, ACOL-2, DRM	Retirement specific ACOL model ("stages" model)	Yes
	Early retirement	adjust for economic factors, predict	ACOL, ACOL-2, DRM	Retirement specific ACOL model	No
Extension					
	Extend, rather than reenlist	adjust for factors affecting extensions, predict extensions	Multinomial choice models	Conditional logit or multinomial probit	No (MOS level) No (aggregate level)
	Reenlistment length	adjust reenlistment length probabilities for economic factors	Multinomial choice models	Probit	No
Skill or Community-specific transactions					
	MOS	separate modules by MOS or CMF to complement aggregate enlisted model, with focus on MOS-specific problems and policies, such as SRB	ACOL, ACOL-2, DRM	ACOL Multinomial models are not a priority at this time	Yes Eventually, econometric models should be reestimated at the monthly level.
	Officer Community	aggregate model for the Army competitive branches with separate, community-specific models for selected officer communities	ACOL, ACOL-2, DRM	ACOL	Yes

Table 1 highlights, once again, that the purpose of the econometric module is to adjust *voluntary* retention rates for changes in pay policies, the state of the civilian economy, and other behavioral factors. Involuntary separations must be analyzed and projected in other components of the Army personnel forecasting system. Reflected in the table is a recommendation for a particular form of retention model, the Annualized Cost of Leaving (ACOL). While more sophisticated economic models of retention behavior are now available in the literature, we believe that the ACOL model does as well as the more sophisticated models for the typical compensation policy issues that are likely to be addressed, such as the effects of general pay increases or reenlistment bonuses.

The models we recommend primarily analyze the simple "stay-leave" retention decision. To consider more complex choices such as extensions or lengths of reenlistment, multinomial models are used. However, we did not uncover a pressing demand for such models based on the policy decisions that are made or on the nature of the reenlistment decision.

Two levels of econometric modules will be necessary in order to address all of the issues, particularly for the enlisted force. An aggregate econometric module, for the enlisted force and for the officer competitive categories, is necessary for overall strength planning and forecasting. This level of aggregation is useful in projecting the effects of general pay raises and the effects of the civilian labor market on retention, in order to provide more accurate strength forecasts as well as to evaluate alternative compensation policies. However, to determine the effects at the MOS level or the level of specific officer communities, and to evaluate targeted incentives such as reenlistment bonuses, an MOS or community-specific level module is necessary. This module may, in fact, be the same general platform as the aggregate module, but substitute MOS-specific parameter estimates for the aggregate estimates. Finally, it is important to note that almost all existing empirical results are for annual models. In the longer run, it is important that the Army sponsor the estimation of econometric models using monthly data, in order to coincide more precisely with the policy application in the Army system.

In the next section, we review the circumstances of specific Army communities, and the implications of these community-specific factors for the econometric model best suited for that community. We apply the general conclusions from our review of econometric models in the preceding section to make recommendations tailored to the specific Army community.

COMMUNITY-SPECIFIC ASSESSMENT

The previous section provided a general discussion of potential econometric models which the econometric module may use to provide insight into the impact of pay changes, policy actions and changes in external economic conditions. The econometric module will contain specific elements for each community to be modeled in the strength planning system.

While individual elements of the econometric module will have different features, the module will maintain a consistent approach. That is, each element will be based on a two-step rate forecast approach that provides adjustments to baseline transition rates and each element's underlying econometric model will be based on an ACOL financial incentive variable. Each element's parameters will be independent of the others, allowing for incremental implementation and updating.

This section of the report considers six personnel communities:

- Enlisted
- Army Competitive Category (ACC) Officers
- AMEDD Officers
- Warrant Officers
- Chaplain Corps
- Judge Advocate General (JAG) Corps

In each of the following sections, we discuss one of these communities. In each, we discuss personnel management and related issues specific to the community, as well as any particular problem areas that are amenable to modeling solutions. Where applicable, we discuss the current modeling environment and existing econometric models. We also make specific recommendations regarding the most appropriate econometric models and any future research that is warranted.

Enlisted Personnel

The enlisted force is probably the most important community for modeling purposes, given its size and relative share in the total budget. The strength-planning system as currently envisioned will continue to project strength at the all-Army level, although a paygrade dimension will be added. A separate element will also contain MOS-specific detail, possibly including a Selective Reenlistment Bonus (SRB) management system.

The nature of enlisted service lends itself to examining enlisted personnel retention behavior in discrete stages, including:

- First-term—YOS 2 through 6
- Second-term—YOS 7 through 10
- Third-term—YOS 11 through 14

- Pre-retirement eligible—YOS 15 through 19
- Retirement-eligible—YOS 20-30

As the previous discussion showed, path-dependent econometric models can be devised and estimated to encompass all career stages for enlisted personnel. The adjustment approach which the econometric module will use cannot take advantage of the dynamic selection aspects of path-dependent models, although these models can be used to provide the underlying parameters.

However, dividing the enlisted career into stages offers several advantages. The first three terms of enlistment encompass both the period in which most soldiers leave the Army and the period to which SRBs apply. The empirical studies reviewed above have concentrated largely on this portion of the enlisted career.

The "pre-retirement" stage is (or has been) characterized by very high retention, notably because of the relative size of retirement versus other financial considerations. Some recent work examined the responsiveness of individuals in this YOS range to separation incentives. The models have generally used an ACOL framework.

A different structural approach may be appropriate to examine the behavior of retirement-eligible soldiers. Because they are already vested in the military retirement system, these soldiers are likely to face shorter decision horizons. Moreover, the guaranteed annuity from military retirement may affect their choices of subsequent civilian careers.

Key Issues for Modeling Enlisted Personnel

The primary concern for the enlisted element of the econometric module is ensuring that voluntary attrition or retention rates are properly separated from involuntary rates. The econometric parameters operate on behavior at ETS points, and their effects should not be imputed to other personnel behavior.

Another potential area of conflict is the use of annual forecasting parameters against monthly decision periods. Particularly when soldiers are able to reenlist early, it may be difficult to apply rates based on an annual period of analysis. The projection process must incorporate seasonality into the adjustment process. The first section of this report outlined some of the problems likely if one attempts to estimate a behavioral monthly retention model. Additional difficulties may arise in the application of parameters from an annual model to monthly retention rates.

Any seasonality in retention rates should already be reflected in baseline retention produced by the strength planning system. Annually-based adjustments to these baseline rates will make appropriate changes to monthly rates unless changes in economic factors also affect the proportion reenlisting early. Such changes would necessitate the estimation of a monthly retention model and the resolution of significant methodological issues. However, even if the econometric module does not capture the seasonality effects of external factors, it will still provide an improvement in predictive capability, since the baseline rates would not reflect economic effects at all.

SRB management at the MOS level may require a different level of analysis. While the previous section described multinomial retention models, the current and proposed systems do not track multinomial decisions. Enlisted extension rates are incorporated in the model and are forecasted by the system. However, Army strength planners view extensions as a separable type of behavior. Soldiers extend for assignment and rotational reasons, not as a distinct occupational choice. Therefore, the econometric module will not directly affect the extension rate.[30]

A multinomial model may still be appropriate at some point to improve the system's ability to predict contracted years of service and SRB cost. A multinomial model could predict the proportions reenlisting for each possible contract length and adjust these proportions for changes in the SRB level.

Recommendations for the Enlisted Element

The enlisted element should initially include the all-Army parameters from the Enlisted Personnel Inventory, Cost and Compensation (EPICC) model. These coefficients cover first- and second-term retention behavior. The second-term parameters can be extended to cover subsequent decision points until further research is conducted. For MOS-level analysis, the econometric module should also use skill-specific retention parameters estimated for the EPICC model. Each MOS must be mapped into a skill group. The current parameters cover three broad occupational groupings—combat arms, technical/mechanical and administrative/clerical.[31]

Reestimation of the enlisted parameters should be a relatively high priority for future research. The EPICC parameters are based on a time series of data that is about ten years old and does not include recent data covering the period of significant drawdowns in force size. Moreover, the period of analysis underlying the parameters is a fiscal year, while the strength planning system tracks at the monthly level.

The improved enlisted retention model should have the following features:

1. Update the time series of historical data underlying the analysis
2. Expand the analysis to measure reenlistment behavior at the monthly level
3. Model the link between SRB award and length of reenlistment
4. Incorporate decisions at later career points (at least the third term)
5. Include information about VSI/SSB offers in the financial variable

[30] Indirectly, however, it might. For a group of soldiers in an ETS window, the percentages who reenlist, leave and extend must sum to 1. An increase in the reenlistment rate may affect the proportion available to extend, unless the model takes extensions out of the available pool first.

[31] See Smith, et. al. (1991).

Modeling Officer Communities

The Army's officer force is divided into (and managed by) several different competitive categories or communities:

- Army Competitive Category (ACC)
- AMEDD
  - Medical Corps
  - Dental Corps
  - Army Nurse Corps
  - Army Medical Specialist Corps
  - Veterinary Corps
  - Medical Service Corps
- Warrant Officer Corps
- JAG Corps
- Chaplain Corps

The econometric module will model officer behavior by these categories, for at least three reasons. The first reason is simply that the strength planning system and, indeed, the personnel management process in the Army manage officers that way.

Second, this division also makes sense from an economic perspective. Officers in different competitive categories face different outside earnings opportunities. The nature of their military jobs is likely to vary (e.g., hazardous duty, arduousness, family separation). We would not expect, moreover, to see the same responsiveness to financial incentives across all of the competitive categories. Third, typical career paths can differ greatly. Promotion opportunities will vary, thus affecting future pay streams.

Finally, econometric analysis offers a higher payoff for some officer categories. Research can be incremental, allowing the module to be operational for the most important categories early on, leaving other communities' parameters for later. As the discussion below makes clear, we do not believe that there is any benefit to incorporating some of the communities right now.[32]

Army Competitive Category

The Army Competitive Category (ACC) covers the largest group of Army commissioned officers. It is the Army officer community for which the most recent econometric retention research has been conducted. Mackin, Hogan & Mairs (1995) estimated the parameters for the model, which is a path-dependent (ACOL-2) model. The period of analysis for this study was FY 1979 through FY 92; the model included YOSs 1 through 15. The Officer Personnel

[32] Although we recommend not implementing the econometric adjustment capability for some communities, from a practical perspective it would be worthwhile to put inactive "placeholders" in the module for those communities. Although invisible to the user, the module would include code and necessary procedures to implement an econometric capability for those communities in the future, should the current assessment change.

Inventory, Cost and Compensation (OPICC) model has incorporated these parameters in a PC-based inventory-projection model currently in use by officer personnel planners.

In many senses, modeling the ACC community will be easier than modeling other officer communities. ACC officers have fewer opportunities for special and incentive pays that obligate them for a period of service. Almost all attrition after the minimum service requirement (MSR) is voluntary. One exception concerns attrition in YOS 12. Officers who fail to select to O-4 (Major) face a high-year tenure point at YOS 12. Mackin, Hogan and Mairs (1995) found that most of these losses appear in the Officer Master File as voluntary separations.

Recommendations for ACC Officers

The Army Research Institute has continued to maintain and update the OPICC model, including a reestimation that incorporates retention decisions through FY 1994. The OPICC model has been validated and shown to provide accurate estimates of the responsiveness of ACC officer behavior to changes in pay and economic conditions (including VSI/SSB). We recommend that the ACC officer element of the econometric module use these parameters.[33]

<u>AMEDD</u>

The Army Medical community is comprised of six sub-groups:

- Medical Corps (MC)
- Dental Corps (DC)
- Army Nurse Corps (ANC)
- Army Medical Specialist Corps (AMSC)
- Veterinary Corps (VC)
- Medical Service Corps (MSC)

The Medical Corps is composed of military physicians—medical doctors (MDs) and Doctors of Osteopathy (D.O.s). The Dental Corps includes Army dentists. These two categories are DOPMA-exempt, meaning that they are not constrained by rules regarding the percentage of field-grade officers in the community. MC officers can enter as direct hires, through the Health Professionals Scholarship Program (HPSP) or through the Uniformed Services University for Health Sciences (USUHS). With the exception of USUHS students, MC officers enter active duty as Captains. USUHS accessions attend medical school as active-duty Second Lieutenants in the Medical Services Corps. Upon graduation, they are promoted to Captain and branch-transferred to the Medical Corps.

[33] New estimates through FY 1996 should be a priority, as there is anecdotal evidence that Army officer perceptions changed during the drawdown. If officers believe their future Army income is less certain, ACOL coefficients before 1991 and after may be substantially different. This possibility should be eliminated before simply using the coefficients from the 1979-1992 estimation.

The Army Nurse Corps contains all Army nurses, including specialists like Nurse Anesthetists. NC officers must have Bachelor's degrees and be state-certified. Most enter the Army through ROTC programs.

The Army Medical Services Corps contains medical administrators, scientists, pharmacists and opticians. The Veterinary Corps handles veterinary duties for all Services; VC officers, like MC and DC officers, enter active duty as Captains. The Medical Specialists Corps includes physical therapists, dietitians and occupational therapists.

The Army does not currently have any econometric models for these personnel, nor did our literature search uncover any behavioral models which could be used for this purpose. Army planners who manage the AMEDD officer communities cited several important management problems which could be addressed by the incorporation of econometric analysis into the strength planning system.

Medical Corps personnel receive retention bonuses that vary by area of specialty. These bonus levels are designed to compensate for differences in civilian-sector demand for these officers, but they can lead to shortages or surpluses for a number of reasons. First, the relative bonus amounts are established at an all-DoD level, while the Army may face particular problems in different areas of specialization than do the Navy and Air Force.

Second, the basis for these bonus adjustments is apparently a survey of employee-physicians in the private sector. Using survey data can be a useful adjunct to other analysis, but relying on it as the sole means to determine pay levels is problematic. Lags between survey administration and the setting of pay may result in inappropriate bonus levels. The specialties in demand two years ago may not be as heavily sought today. Pay comparability only works if the jobs really are comparable. Working conditions in the Army and in civilian health care may differ drastically. Third, because the survey focuses on employee physicians, it ignores the earnings potential many physicians face if they leave the Army and become self-employed (e.g., starting or joining a medical practice).

Army personnel managers who were interviewed cited incorrect bonus levels as a chief reason that periodic shortages and surpluses *by specialty* routinely occur in the Medical Corps. An econometric model that measures the responsiveness of these medical doctors to changes in pay levels may be an extremely valuable addition to the econometric module.

There are no existing econometric modules of Army medical officer retention behavior. The ACC model described above would be inappropriate for Medical Corps officers because physicians face drastically different alternative earnings opportunities. Also, the promotion path for Medical Corps officers is different. They may enter the Army at pay grades above O1 and face non-competitive promotion paths to grades as high as O6. Finally, the Medical Officer Retention Bonus, as well as accession programs, carry service obligations that must be considered to properly isolate voluntary retention decisions.

Manning levels in the ANC are also volatile and extremely sensitive to changes in the civilian-sector demand for nurses. Nurse demand and alternative wages may also vary by specialty. Army personnel specialists also identified AMSC and DC as areas of volatility in personnel supply and demand.

Recommendations for AMEDD Officers

The AMEDD element of the econometric module will require new research to establish a set of parameters. The econometric models of retention behavior should follow the ACOL approach and have the following features:

- Vary by specialty or groups of specialty within the MC, ANC and (possibly) DC communities
- Recognize the link between length of commitment and the size of bonus
- Utilize earnings estimates specific to their likely alternative jobs
- Explore alternative measures of employment demand (i.e., use sector-specific measures of demand in place of aggregate unemployment rates)

This approach is discussed in greater detail in the Research Plan.

Warrant Officer Corps

As is the case for AMEDD branches there are currently no Warrant Officer economic models of retention behavior. Warrant Officers comprise a fairly large portion of the officer force (currently about 12,000 officers). Warrant Officers follow two different accession paths. Aviators generally enter directly into Warrant Officer Corps, while Technicians transfer from the enlisted force (usually in YOS 6-10).

Accordingly, total years of active service will remain important because of the relative value of retirement, but years of service as a Warrant Officer will be more important for determining promotion opportunities and career progression.

Currently, the Army is unable to predict accurately how Warrant Officers will respond to pay incentives. In a recent example, Warrant Officers were offered a Voluntary Early Retirement Program (VERP). The Army's goal was to get 1,000 takers; 5 officers accepted the offer.

Recommendations for Warrant Officers

We recommend the development of an econometric retention model focused on Warrant Officers with 0 to 20 years of service. Preliminary analysis may focus on determining whether Warrant Officers with significantly fewer years of service as Warrant Officers tend to leave later than 20 years.

The model must distinguish between officers who enter directly into the Warrant Officer Corps from the civilian sector and those who transfer from the enlisted ranks. Depending on differences in career progression and promotion, these distinctions may be accommodated simply in the specification of the financial variable or by specifying two separate models.

Aviators may have well-defined alternative employment opportunities; moreover, there may be a natural "jumping-off" point at which aviators have acquired the minimum experience required for jobs in the civilian sector. Likewise, Technicians may or may not have specific job skills that are transferable to civilian jobs.

JAG Corps

Officers in the Judge Advocate General (JAG) Corps are attorneys and therefore have well-defined alternative career opportunities. However, the JAG Corps is small relative to other communities and does not face any significant personnel management problems.

JAG Corps officers do not receive any retention pays, nor has retention been a problem. JAG Corps officers are acquired in three ways:

- Direct accessions
- ROTC deferments (i.e., ROTC students attend law school before entering the Army)
- Laterals from other Branches (the Army sends them to law school)

Recommendations for JAG Corps Officers

We recommend that the econometric module contain a JAG Corps element as a "placeholder" should future management issues arise that create a need for analytical capabilities. Currently, however, we do not feel that a JAG Corps model is warranted.

Chaplain Corps

The Chaplain Corps, like the JAG Corps, has a small number of officers and few management problems. The only chronic shortages currently are among Roman Catholic and Jewish Chaplains.

The most unique aspect of this Branch is the "Dual Chain of Command." That is, while all Chaplains are responsible to their Army chains of command (just as any officer is), they are also responsible to their sponsors. This reliance on their sponsors can make it difficult to distinguish voluntary and involuntary behavior. Also, it would be difficult to identify the value of alternative opportunities for Chaplains from some denominations.

Recommendations for Chaplain Corps Officers

We recommend that the econometric module contain a Chaplain Corps element as a "placeholder" should future management issues arise that create a need for analytical capabilities. Currently, however, we do not feel that a Chaplain Corps model is warranted.

Summary and Conclusions

The econometric module should provide individualized elements for the major Army personnel management communities, including

- Enlisted personnel
- ACC officers
- AMEDD officers
- Warrant officers
- JAG Corps officers
- Chaplain Corps officers

Further, the model should include skill-specific elements or sub-groupings for the enlisted and AMEDD communities. Other features will include a capability to model the impact of changes in the SRB plan on MOS-level reenlistment rates, and specialty-level estimates of changes in retention rates for Medical Corps officers.

Currently, there are solid candidates for the parameters to be used in the enlisted and ACC elements, although the enlisted parameters are somewhat dated. New research for enlisted models should focus on developing a model at the monthly, rather than annual, level and on expanding the available set of retention parameters beyond the second reenlistment point. New research is necessary to produce useful parameters for Warrant Officers and AMEDD officers. While the module should contain Chaplain Corps and JAG Corps elements in its design, the potential benefits of analysis for those communities do not seem to justify the investment.

SUMMARY AND CONCLUSIONS

This study has examined the role of an econometric module in the Army's strength planning system. We have considered how the module will be integrated with other elements of the system; which econometric approaches are most appropriate for the proposed module; and which Army communities should be included. Based on this analysis, we can make the following general recommendations about the module:

1. Structuring the econometric module so that it modifies baseline rate forecasts appears to be most compatible with the cell-based Markov-type of personnel forecasting system planned for continued use by the Army. This implies a two-step rate forecast when the econometric module is applied.

2. A module that uses the ACOL financial incentive variable appears to provide the greatest flexibility. It addresses the "horizon" problem in a rational and consistent way. Though less rigorous and flexible than the DRM for some policy questions, it is much easier to manipulate than the multiple horizon dynamic programming model. Finally, its parameters can be estimated from either the ACOL or ACOL-2 formulation, but applied within the context of the Markov assumptions.

3. For enlisted personnel, the module must adjust monthly reenlistment rates. Existing research has focused on annual decisions; therefore, in the near term the module must make some adjustments to adapt the annual estimates to monthly forecasts. In the longer term, a monthly retention model for enlisted personnel is important.

4. Skill-level (MOS-specific) models for SRB planning may be an appropriate application. Multinomial models do not appear to be necessary. Extension behavior appears to be tied to assignments and rotational considerations, rather than voluntary, occupational-choice decisions.

An important part of the analysis was to examine each Army community and determine the most appropriate econometric method. While consistency in the general approach is desirable, some differences in the retention models are inevitable because of differences in personnel behavior and career paths. Also, we evaluated existing models to determine whether their parameters were appropriate for the econometric module.

The enlisted element of the econometric module is the most critical, given the size of the enlisted force and the relative impact it has on the Army's personnel budget. Existing models provide annual retention parameters at the all-Army and skill levels for first- and second-term reenlistment behavior. Priority should be given to new research that provides estimates of monthly retention behavior and incorporates new time-series data including the period of the drawdown. MOS-specific or skill-level estimates are necessary as well for SRB planning.

The existing retention model for ACC officers provides adequate parameters for the ACC element of the econometric module. No additional research is warranted presently, although the parameters should be reestimated in the future to incorporate newer historical data, particularly for the full drawdown period.

AMEDD officer branches also require an analytical capability within the econometric module. These officers are subject to well-defined sets of alternative career opportunities and are often costly to recruit and retain. There are no existing Army models of AMEDD officer retention; estimation of a set of models for these branches is a high research priority. The models should vary by specialty within the Medical Corps and the Army Nurse Corps. A Dental Corps model is also needed. Models for remaining AMEDD groups are also needed, but are a lower priority. AMEDD retention models must account for the link between length of commitment and retention bonuses and use information about sector-specific earnings and employment opportunities.

The Warrant Officer element likewise cannot draw upon any existing research for economic parameters. We recommend development of a model or set of models, possibly distinguishing between Aviators and Technicians.

The final two officer communities, JAG Corps and Chaplain Corps, are small, well-managed communities. We do not feel that empirical research is justified for these groups, but the econometric module should contain "placeholder" dimensions for them.

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APPENDIX A: DESIGN SPECIFICATION

Introduction

This appendix provides the technical specifications for the econometric module of the ODCSPER Manpower Models. The purpose of this appendix is to offer the necessary information to develop a module that allows Army users to estimate the impact of changes in pay, economic conditions and personnel policies on underlying transition rates. These changes will be based on parameters estimated in separate econometric research (see the Research Plan).

The first part of this appendix is an overview of the econometric module and its relationship to the rest of the strength planning system. The second part provides more detailed information about the module's interface with the rest of the system. The third section describes additional data requirements and the fourth section discusses the user interface. The fifth section presents the computational algorithms which the module will use to adjust rates and the final section describes the module's output.

Overview

Figure 1 presents a top-level view of how the econometric module will function within the overall system. Transition rates that are generated within the system will be passed to the econometric module. The econometric module will use system data, additional baseline data and user settings to predict changes in these rates. The adjusted rates are passed back to the system.

Note from Figure 1 that the econometric adjustment is an optional procedure applied to the system's forecasted rates. The user can still use the default or baseline forecasted rates to project strength. If the econometric module is used, the adjusted rates are used in the projection process instead.

As we will describe in more detail below, the crucial factor in designing the econometric module is to ensure that it can make the adjustments compatibly with the system's dimensions. The adjusted rates must be passed back in the same format in which they were provided. This restriction also imposes some constraints on the design of the overall system.

Another critical decision concerns the integration of the module into a projection. Perhaps the simplest method is to allow the main forecasting model to project rates for the entire period of analysis (assuming a multi-year analysis). These rates are then passed to the econometric module, which makes adjustments and returns the rates to the strength projection portion of the model. Alternatively, the adjustment can occur within a projection-year loop. Year 1 rates are adjusted, the model projects Year 1 endstrength, then Year 2 begins.

The best option will depend to a large extent on how the system forecasts rates. If the outyear projections depend on changes in personnel distribution, it would be better to make the econometric adjustments within the projection-year loop, rather than at the end of the process.

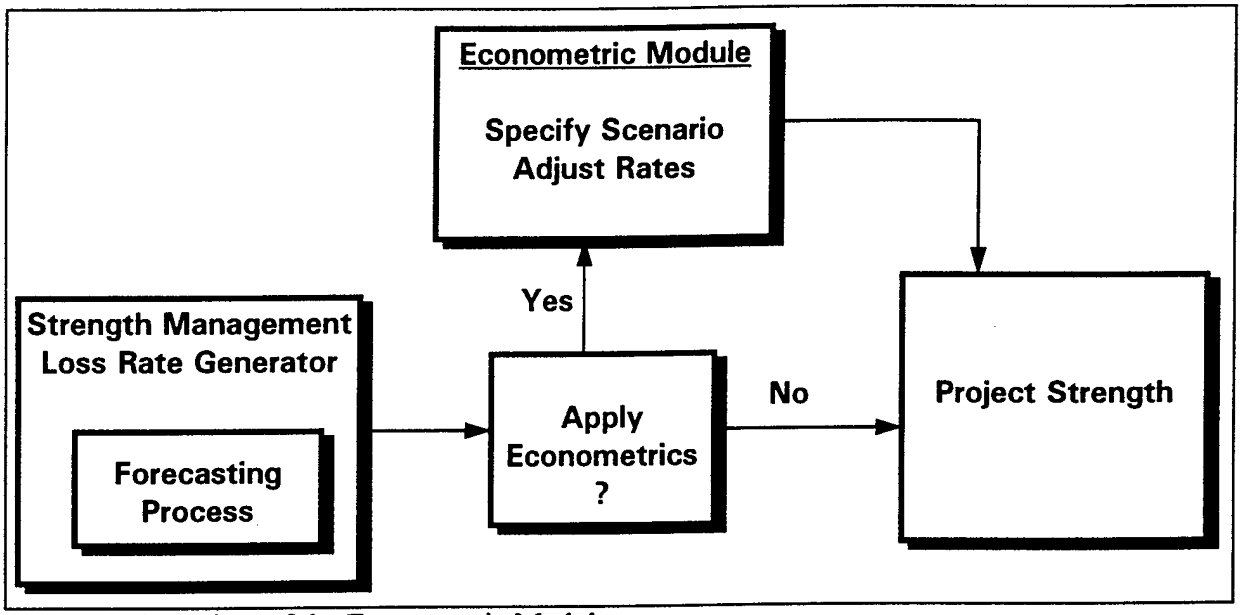

Figure 1. Overview of the Econometric Module

This design specification will not address the issue of software or hardware environment, although the econometric module has been conceived as a PC-based analytical tool that is linked to the main strength management system. The development environment for the econometric module should be consistent with user facilities and with the overall project.

Interface with Personnel System

This appendix cannot provide detailed information about how the econometric module will interface with the rest of the personnel system, because the redesign of the system is still in its early stages. Instead, this section focuses on describing the type of interface which the econometric module should have with the rest of the system and what requirements this interface may impose on the system.

Of primary concern for the econometric module is the format in which transition rates are provided from the main system. Specifically, transition rates must be separated to distinguish *voluntary* from *involuntary* behavior. For the enlisted element of the model, the econometric module will only operate upon attrition rates for personnel who are eligible to make a contract decision.

The econometric module will also further distinguish types of voluntary transition behavior. For example, the attrition parameters will probably vary across reenlistment zones or career phases. Also, the parameters will vary by community. Therefore, the main system must provide sufficient information to identify the rates in this manner. Career phase or zone may simply be handled by using YOS as a rate dimension.

The econometric module must also receive baseline inventory data from the main system. For the structural econometric models proposed in this design, inventory should be dimensioned by YOS and pay grade in order to provide estimates of expected future earnings. If the main inventory data are stored in greater detail (i.e., more dimensions), they will have to be summed across all other dimensions. Alternatively, the module may rely on alternative methods to predict future promotions and, thus, to calculate expected pay.

Additionally, the main system may be able to provide demographic data on the community being modeled. The calculation of the earnings variable (ACOL) will require information on the dependents status, race and gender of the population.

Data can be transferred from the main system to the econometric module either by designing the main system to write a data file which the econometric module will use or by designing the econometric module to access the main system's databases and extract and process the necessary information.

Other Data Requirements

The main system will provide the econometric module with transition rates to be adjusted and with inventory data at least dimensioned by YOS and pay grade. In addition, it may be able to provide some demographic summary data needed for the calculation of the earnings variables. All other necessary data will reside exclusively in the econometric module.

The additional data will be imported or entered through the econometric module's user interface. Spreadsheet-type editing screens will permit easy importing of data from other applications.

Pay and Economic Data

Military pay data will be used to calculate expected military earnings for the base period and for the projection periods. At a minimum, this data will include basic pay tables, military allowances and key special and incentive pays.

Civilian-sector economic data will also be necessary. Consumer Price Index (CPI) deflators will be used to adjust earnings estimates into constant dollars. Current Population Survey (CPS) or other civilian earnings data must be used to adjust alternative earnings streams as well.

Personnel Data

Any personnel data which the main system does not provide must be stored directly in the econometric module. These data would include information on the gender, racial and marital characteristics of the population. The section below that provides the module's algorithms explains how these data are used in the calculation of the earnings variable (ACOL).

Depending on the extent of data needed, the module can be designed to either import the data from external sources or simply to allow users to enter the data on spreadsheet-type screens.

User Interface

The econometric module will have its own user interface that serves three functions

1. Input additional data required by the module and not provided from the main system
2. Specify run parameters (e.g., community, base year) and policy scenario (e.g., pay and economic changes)
3. Specify output options

We envision the module being run from an analyst's PC, preferably as a Windows-based application. Windows applications make transferring data among applications much easier.

Figure 2 shows the user interface and its relationship to the module's various elements. The analyst specifies a particular scenario, which may include changes to military pay or civilian-sector economic conditions, the establishment of retention or separation incentives, or changes to the military retirement system. The analyst must also specify the community being modeled.[33]

The module imports and maintains data from a number of sources, including the main system. Some data may be imported in machine-readable format from other sources or may simply be entered by the user.

[33] This specification may be handled as well by having separate modules for each community. The user selects a community by choosing the appropriate module. Even in this case, the separate modules can share common components.

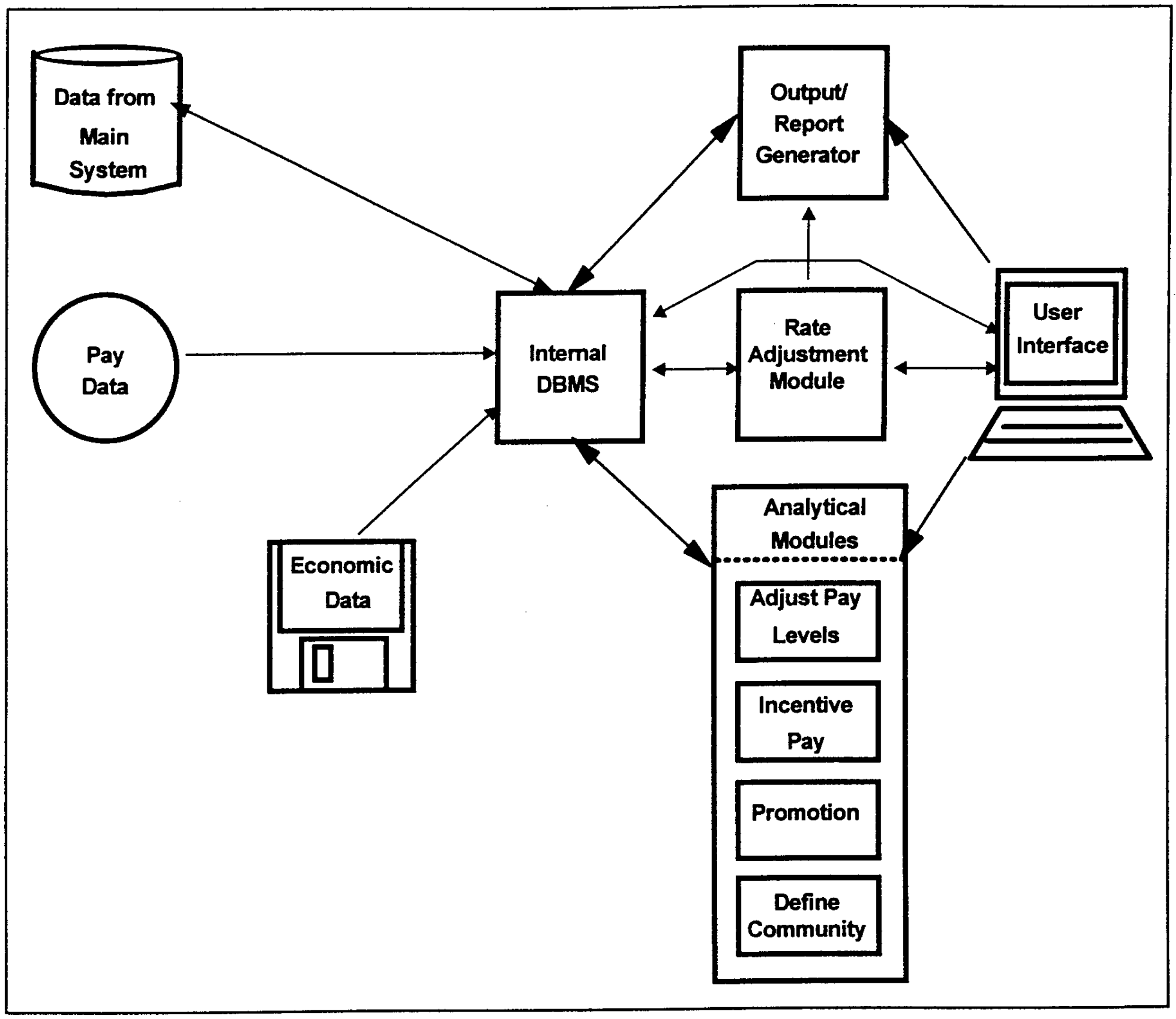

Figure 2. Econometric Module and User Interface

Algorithms

This section presents the algorithms used to adjust rates using the econometric parameters. These algorithms include the formulas used to calculate ACOL values and the equations that produce the adjustments to input transition rates.

The form of the financial variable will depend on the structure of the underlying econometric equation. This design specification is based on the adoption of an ACOL equation for the adjustment process. If the Army substitutes alternative models, the appropriate algorithms must be substituted in place of the ACOL calculation.

The following sections describe the calculation of the ACOL variable and the algorithms for adjusting transition rates.

Calculation of the Financial Variable

The first section of this appendix discusses various approaches to modeling the impact of financial factors on retention behavior. We concluded that section by positing that structural (rather than ad-hoc) models were better suited to support the types of policy analysis envisioned for the econometric module.

Structural economic models of retention behavior consider the stream of pecuniary and non-pecuniary returns to alternative career paths. They are based on a decision rule. The individual will stay if and only if the returns to staying exceed the returns to leaving:

$$(M-C)+(\gamma_M-\gamma_C)\geq 0,$$

where (M - C) is the net pecuniary returns to staying and (γ_M - γ_C) is the net non-pecuniary taste for the military.

The models must consider multiple horizons across which individuals may make a decision to leave the Army. Two structural approaches which we considered were the ACOL model and the Dynamic Retention Model (DRM).[34] While the DRM solves endogenously for the probabilities associated with each possible path, the ACOL model uses an arbitrary (albeit reasonable) rule: if the individual will not stay for the horizon for which the ACOL is maximized, he or she will not stay for any horizon. We have recommended this approach for the econometric module because of its proven record in policy analysis and because of the relative computational complexity of the DRM.

In theory, ACOL equals the difference between expected military earnings and alternative civilian earnings (M - C) and the value of the non-pecuniary factors affecting retention, including the "taste" component. For the estimation model, however, tastes appear implicitly in the error term. Thus, the ACOL variable used here includes two elements: military and civilian earnings.

The model is normalized by expressing returns as the difference between the returns to staying in the military and the returns to leaving immediately (hence, the "cost of leaving"). The pay variable is the difference between expected lifetime earnings if the individual stays until some optimal horizon and expected earnings if he/she leaves immediately.

The ACOL model assumes that an individual will leave immediately only if the ACOL value associated with each possible horizon is not large enough to offset the net non-pecuniary costs of staying. This implies that a worker will stay if there is at least one horizon for which the returns to staying exceed the returns to leaving. The ACOL variable is defined as the maximum pay difference over all possible horizons.[35]

[34] The ACOL-2 model is a path-dependent application of the ACOL model; calculation of the financial variable is identical to the path-independent case.

[35] Warner and Goldberg (1984), pp. 14-15. Note that the ACOL measure should be considered an index describing the financial incentive to stay at least one more year. The horizon associated with the maximum ACOL value is not necessarily the optimal leaving point.

To calculate the ACOL variable, assume that an officer or soldier can stay in the Army for a maximum of n more years, and will stay in the labor force T more years, regardless of when he/she leaves the Army.[36] Then, calculate the following variables for n possible horizons:

1. M_k = expected military pay in year k (k = 1, 2,..., n).
2. W_{k0} = future potential civilian earnings from leaving immediately (k = 1, 2,..., T).
3. W_{kn} = future potential civilian earnings from staying n more years, where civilian wages are conditional on n years of military experience (k = n+1, n+2,..., T).
4. r = the personal discount rate.
5. d_k = (1/(1+r))k (k=1,...,T).

The cost of leaving (C_n) is the discounted stream of pay differences over the T-year horizon:

$$C_n = \sum_{k=1}^{n} M_k\, d^k + \sum_{k=n+1}^{T} W_{kn}\, d^k - \sum_{k=1}^{T} W_{k0}\, d^k$$

Rearranging terms,

$$C_n = \sum_{k=1}^{n} d^k\,(M_k - W_{k0}) + \sum_{k=n+1}^{T} d^k\,(W_{kn} - W_{k0})$$

The annualized pay difference (A_n) is expressed as:

$$A_n = \frac{C_n}{\sum_{k=1}^{n} d^k}$$

The ACOL value used in the retention equation is

$$max_n\, A_n = A_n^*$$

where the horizon, n, maximizes the annuitized difference between military and civilian pay.

Military compensation may be composed of a number of elements, depending on the specification of the retention equation and on user settings as well. Some of the elements typically included in M_i are

- Regular Military Compensation (composed of Basic Pay, Basic Allowance for Quarters, Basic Allowance for Subsistence and Variable Housing Allowance
- Special and Incentive Pays, including Selective Reenlistment Bonuses for soldiers in crucial shortage skills

Other returns to staying include the present value of military retirement associated with horizon n; any separation incentives expected at n; and the stream of expected civilian earnings from horizon n to retirement from the labor force.

[36]This specification of the pay variable is derived from Warner and Goldberg (1984), p. 27.

The returns to leaving immediately consist of the stream of expected civilian earnings from the decision point (i) to retirement from the labor force; the present value of military retirement at the decision point (i);[37] and the value of any separation incentives available at i.

The cost of leaving at YOS i rather than YOS n can be expressed as

$$C_n = \sum_{k=1}^{n} d^k \left(M_k - W_{k0} \right) + PVRET_n - PVRET_i + PV(EXBON_n) - PV\left(EXBON_i\right) + \sum_{k=n+1}^{T} d^k \left(W_{kn} - W_{k0} \right).$$

We next consider how each of these variables may be calculated.

The underlying econometric parameters are based on estimates expressed in constant dollars. Each of the calculated pay streams must be deflated into the appropriate dollars. The econometric module will contain historical and projected CPI rates which will be used to deflate the estimates. Within the analysis period, the user must specify annual inflation rates to permit the ACOL calculation to adjust out-year estimates as well.

Regular Military Compensation. The econometric module must contain baseline data with the appropriate pay tables for each element of RMC. These elements are dimensioned by YOS, paygrade and/or dependents status. Variable Housing Allowance is also dimensioned by duty location, so the model should contain all-Army averages. These tables are converted into expected RMC by averaging across paygrades for each YOS according to the distribution of personnel in the underlying inventory. For example, RMC_i equals RMC for E-1s in YOS i times the percentage of personnel in YOS i who are E-1s plus RMC for E-2s in YOS i times the percentage of personnel in YOS i who are E-2s, etc.

An alternative method for computing expected RMC is to incorporate a promotion model and predict expected paygrade by horizon YOS, conditional on current YOS. This approach imposes additional computational burdens on the model and it is unclear whether it will yield better predictions at an aggregate level. If this approach is handled strictly within the econometric module, the module will need a separate element to model promotion probabilities, possibly requiring more detailed data from the main system. Alternatively, it is conceivable that the main system, which in the redesign will include a paygrade dimension, could already contain a model of promotion likelihood. This model could alternatively be used to predict expected military earnings.

There are at least three options for handling the with- and without-dependents differentials in the military allowances. First, the module could use demographic information from the main system's data if it is available to determine the percentage without dependents by YOS. Second, the module could be hard-coded with percentages. Third, the user could provide these percentages. The third option may be most practical. Previous research has shown that the percentages with and without dependents do not vary much across communities or across time.

[37] For most decisions, this is equal to zero.

It may be enough to load default values that apply to all enlisted, warrant or commissioned officers.

Once RMC is calculated, it must also be deflated into base-year dollars for the underlying analysis. Across the projection period, the user must specify pay raises, either for all of RMC or by element.

Military Retirement. The value of retirement for any YOS in the member's horizon equals the increase in retirement pay from staying until that horizon year. The value is zero for YOSs less than or equal to 19; the values for YOSs 20 through 30 increase with rising vesting percentages and expected basic pay. Three systems are currently in effect.

Those personnel who entered active duty before September 1980 fall under the original retirement plan. Under this system, the member vests at the completion of 20 years of creditable service (the end of YOS 20). The retirement annuity associated with a given horizon YOS (20 or higher) is

$$Annuity = BPAY_i * i * 0.025 .$$

Thus, an officer or soldier retiring after 20 years receives 50% of basic pay, while he/she would get 75% after 30 years. The annuity increases annually to keep pace with the Consumer Price Index.

Personnel accessing after August 1980, but before August 1986, fall under a second retirement system. While their annuity is similar in terms of percentage of pay and vesting point, it is based on an average of their highest three years' basic pay:

$$Annuity = (High\ Three)_i * i * 0.025.$$

The final system pertains to officers entering active duty after July 1986. While the vesting years are also 20 through 30, the percentages vary from 40% to 75%. For this case,

$$Annuity = (High\ Three)_i * (i * 0.035 - 0.3).$$

Retirement benefits are also adjusted for inflation. The Cost of Living Adjustment (COLA) under the newest system is one percentage point less than the CPI from retirement until age 62. At 62, the annuity makes a one-time catch-up to recover the inflation losses. After catching up, it reverts to the "CPI - 1" adjustment, but converts the pay percentage to the original calculation ($[HighThree]_i * i * 0.025$).

Retirement pay is expressed in terms of present value. The ACOL calculation must assume an age at retirement and a number of years that the member will expect to receive the annuity. Since the annuity should (theoretically) stay constant in real dollars, the present value of the stream of payments (at the time of retirement) equals

$$PV(Retirement) = Annuity * \frac{1}{r}\left[1 - \frac{1}{(1+r)^t}\right].$$

Here, r is the personal discount rate and t is the number of years for which the annuity is received. Under the final (Redux) retirement system, however, the real value of the annuity will fall every year until the catch-up.

Depending on the analytical questions which users are addressing, the econometric module may include provisions allowing users to specify new retirement scenarios. These scenarios may include new vesting points or new methods for calculating retirement annuities.

Civilian Earnings. Most of the econometric retention models which will be used in this module estimate civilian earnings using an equation in which the log of earnings is regressed on years of experience and demographic factors that are associated with earning potential (e.g., education, race, sex). Many of these equations distinguish between the returns to civilian experience and the returns to military experience, under the premise that on-the-job training in the military may not be directly applicable to jobs in the civilian sector. If the underlying earnings estimate does not distinguish between military and civilian experience, the ACOL equation can drop the terms that calculate W from n to T (i.e., from the horizon year to retirement from the labor force), since the two streams will cancel out.

The coefficients from the civilian earnings equation are used to generate expected earnings streams. Demographic data can be used in the same ways that dependent status enters into the RMC calculation—using system data to get average values, allowing the user to specify values or setting defaults in the code.

Two additional adjustments are necessary to calculate civilian earnings. First, the earnings estimates must be adjusted to base-year dollars consistent with the underlying econometric equation. Second, the estimates must be adjusted to account for real wage growth between the base year and the analysis year. Note that "base year" does not refer to the first year of the projection run, but rather to the year to which all nominal dollar values were converted in the estimation of the parameters of the econometric model.

Current Population Survey (CPS) data or other comparable information can be used to construct indexes for initial adjustment. The user must also specify civilian pay raises across the period of analysis.

Separation Incentives. A final element of military pay is the Voluntary Separation Incentive/Selective Separation Bonus (VSI/SSB) program. Since FY92, the Army has offered lump-sum or annuity separation payments to some officers and enlisted personnel to induce them to leave the Army early. The econometric module may also permit a more flexible scenario construction for exit bonuses. Any exit bonuses that are included must be converted to a lump-sum present value to be included in the analysis. They also must be deflated into real base-year dollars.

Adjusting Transition Rates

The adjustment of transition rates within the econometric module will be based on changes in the predicted value of the financial variable (ACOL). We assume that the set of economic and policy conditions observed for the base year produced both the end-year inventory and the retention rates observed for the base year. The econometric module will calculate the

Annualized Cost of Leaving (ACOL) variable associated with each inventory cell for the baseline pay and economic data. Changes in retention rates are then calculated based on *changes* in the ACOL variable and changes in the unemployment rate.

Therefore, the module must calculate a baseline ACOL value corresponding to each cell in the rate matrix that it is adjusting. For each analysis year, it will calculate a new ACOL value. The value may change because of general pay raises, changes in bonuses or other special pays or changes in civilian-sector economic conditions.

The underlying econometric equations are typically specified as probit or logit models. The adjustment algorithm will vary slightly depending on which form is used, so we present both here.[38]

A simple example illustrates the method using probit coefficients. Suppose individuals in YOS j exhibited a retention rate in the base year of 0.90 and that the calculated ACOL value for those individuals is $ACOL_0$. Assume the base unemployment rate is 6.0 percent. Another way to look at the retention rate is as the probability that an individual in that inventory cell will stay:

$$P_{j,0} = 0.9.$$

In the structure of the retention equations estimated for this model, these probabilities follow the cumulative standard normal distribution (Φ):

$$P_{j,0} = \Phi(Z_{j,0}) = 0.9.$$

For the base retention rates, the adjustment algorithm solves for the associated "Z" value (probit index). In this example, Z ≈ 1.2816.

For projection year *i*, the algorithm calculates the new ACOL values for each inventory cell. It subtracts the base ACOL value from the new value to get the net change in the pay variable resulting from all of the policy scenario information provided by the user. It also calculates the change in the national unemployment rate. These changes are multiplied by the appropriate econometric parameters (β_A and β_U) and added to the base Z value to produce the new predicted retention rate:

$$P_{j,i} = \Phi\left[Z_{j,0} + \beta_A(ACOL_{j,i} - ACOL_{j,0}) + \beta_U(U_i - U_0)\right].$$

This adjustment technique is currently used in the Army's Officer Personnel Inventory, Cost and Compensation (OPICC) model and is documented in the OPICC user's manual.

The process for using logit coefficients is analogous. In the logit formulation,

$$P_{j,0} = \frac{1}{1+e^{-Z_{j,0}}} \text{ and } Z_{j,0} = \ln\left[\frac{P_{j,0}}{1-P_{j,0}}\right].$$

Then,

[38] If the underlying research includes both formats, it may be more efficient to convert parameters for some of the equations so that all of the parameters are of the same form.

$$P_{j,i} = \frac{1}{1+e^{-\left[Z_{j,o} + \beta_A(ACOL_{j,i} - ACOL_{j,o}) + \beta_U(U_i - U_o)\right]}}.$$

The Army's Enlisted Personnel Inventory, Cost and Compensation (EPICC) model uses this adjustment technique.

APPENDIX B: RESEARCH PLAN

The econometric module which has been proposed for the Army strength management system will require a significant investment in research in order to improve existing parameters and to add parameters for several Army communities. However, this significant investment can be distributed across time. This research plan summarizes and prioritizes the future research suggested by the module's proposed design.

The research plan is intended as a general guideline. Key design issues must be resolved in the course of each individual project. We do not attempt to make specific recommendations about how each model should be estimated. Where possible, however, we have identified necessary or important features.

The research required for the econometric module includes the following projects:

- AMEDD retention models
    - Medical Corps by specialty
    - Army Nurse Corps by specialty
    - Dental Corps
    - Remaining AMEDD groups
- Warrant Officer retention models
    - Aviators
    - Technicians
- Enlisted personnel monthly retention model
- Skill-level enlisted model

We have attempted to prioritize this future research, based on our review of existing models and the Army's analytical needs. However, we recognize that the Army may attach more importance to some of the research lower on the priority list. The remainder of this appendix briefly reviews the requirements for the proposed research.

AMEDD Retention Models

The AMEDD element's econometric models of retention behavior should follow the ACOL approach and have the following features:

- Vary by specialty or groups of specialty within the MC, ANC and (possibly) DC communities
- Recognize the link between length of commitment and the size of bonus
- Utilize earnings estimates specific to their likely alternative jobs
- Explore alternative measures of employment demand (i.e., use sector-specific measures of demand in place of aggregate unemployment rates)

Army officers in the medical community have very specific civilian career opportunities, which will make it easier to identify the opportunity cost of continued Army service. The analysis should address differences in earnings and career opportunities across specialties and across different elements of the AMEDD branches.

For example, Medical Corps officers in certain specialties may be more likely to become self-employed physicians, while other physicians may have more opportunities as employee or staff physicians. Self-employed physicians may have different optimal leaving points than employee physicians—starting up a practice, buying an existing practice or entering a group practice may require a significant up-front investment that demands a fairly long pay-back period.

The models for AMEDD officers are likely to be closer in form to the enlisted models than to other officer models. The existence of retention bonuses, particularly for Medical Corps officers, means that many officers will be serving under obligation for discrete periods. Therefore, it would be unrealistic to model their behavior as if they were continually able to make voluntary stay/leave decisions.

Initial investigations should include a review of any work conducted or sponsored by the Assistant Secretary of Defense for Health Affairs.

<u>Warrant Officer Retention Models</u>

We recommend the development of an econometric retention model focused on Warrant Officers with 0 to 20 years of service. Preliminary analysis may focus on determining whether Warrant Officers with significantly fewer years of service as Warrant Officers tend to leave later than 20 years.

The model must distinguish between officers who enter directly into the Warrant Officer Corps from the civilian sector and those who transfer from the enlisted ranks. Depending on differences in career progression and promotion, these distinctions may be accommodated simply in the specification of the financial variable or by specifying two separate models.

Aviators may have well-defined alternative employment opportunities; moreover, there may be a natural "jumping-off" point at which aviators have acquired the minimum experience required for jobs in the civilian sector. They will also have additional incentives to stay in the Army (e.g., Aviation Career Incentive Pay). Likewise, Technicians may or may not have specific job skills that are transferable to civilian jobs.

<u>Enlisted Personnel Monthly Retention Model</u>

The enlisted element of the econometric module will initially include parameters based on annual retention decisions adjusted to reflect monthly rates. Because reenlistments are explicitly tracked by month within the strength management system and the timing of reenlistments within a fiscal year is important for budget analysis, the first priority for enlisted analysis is a monthly model of reenlistment behavior. At the same time, the model should incorporate new time series data and expand the analysis to consider decisions beyond the second reenlistment point.

The monthly retention model must dynamically consider eligibility to reenlist as a function of ETS and the current reenlistment eligibility rules. For example, the eligibility "window" changed in October 1996 so that soldiers are eligible to reenlist from twelve months before ETS to three months before ETS. A monthly model will have to account for the size of this window, as well as the soldier's relative position within the window (i.e., a soldier who has not reenlisted after being eligible for three months is less likely to reenlist than an otherwise similar soldier just entering the reenlistment window).

Skill-Level Enlisted Retention Model

Below the all-Army level, econometric reenlistment models can be used to manage the SRB budget. Some monthly or quarterly targeting may be appropriate, but an annual model may be sufficient.

SRBs are paid at the MOS level, but it is neither necessary nor desirable to estimate separate sets of parameters for each MOS. Rather, one of the first tasks for this project is to identify key groups of MOSs which can be aggregated into larger occupational groupings for analysis. This categorization will be based both on Army-specific considerations (e.g., MOSs with similar career paths and working conditions) and external considerations (e.g., MOSs with similar alternative career opportunities).

While the focus of these models will be SRB management, they should also employ a methodology that is consistent with other elements of the econometric module. For example, they should use an ACOL-like earnings variable rather than an ad-hoc specification (e.g., SRB multipliers used directly as explanatory variables). In addition to maintaining flexibility, this approach has the added advantage of ensuring consistency across elements. In other words, for a given change in pay or economic conditions, the SRB module will predict change of about the same magnitude as does the all-Army model.

Summary

Table 2 outlines a timetable for this research plan and provides estimates of the level of resources necessary for each phase.

Table 2
Timetable and Estimated Resources for Proposed Research Plan

Proposed Research	Timetable	Resource Level ($K)
AMEDD Retention Models		
Medical Corps	First year of new system	200
ANC	First year of new system	150
DC	Second year of new system	75
Other	Second year of new system	100
Warrant Officer Retention Model	Third year of new system	150
Enlisted Monthly Retention Model	Fourth year of new system	250
Enlisted Skill-Level Retention Model	Fifth year of new system	150

APPENDIX C: REVIEW OF EMPIRICAL RETENTION LITERATURE

Enlisted Models and Empirical Results

The simple ACOL model has been estimated for enlisted retention behavior in the Navy (Warner and Goldberg, 1984) and for each of the military Services in the aggregate (Enns, Nelson and Warner, 1984). Mackin (1992) re-estimated the Warner-Goldberg Navy model using more recent data (FY 1978 through FY 1989). Mackin also expanded the analysis to include third-term reenlistment behavior. While Warner and Goldberg initially estimated their model on grouped data for a three-choice decision (reenlist-extend-leave) and on individual data for a two-choice decision (stay-leave), Mackin employed a conditional logit specification on individual data. These updated estimates indicated somewhat lower responsiveness of reenlistment probabilities to changes in pay levels.

Mairs, Mackin, et. al. (1989) estimated a four-Service ACOL model for the Office of the Secretary of Defense (OSD). This two-choice model used data for enlisted personnel making retention decisions in the first three terms of service. Retention decisions were grouped by Service, YOS, quality, race and gender. The estimated coefficients from this study were incorporated into a four-Service inventory projection model used by OSD Compensation and the Seventh Quadrennial Review of Military Compensation. They were later incorporated into a projection model developed by RAND–the Compensation, Accession and Personnel Management (CAPM) Model.

The ACOL-2 model was estimated for Navy enlisted personnel (Black, Hogan and Sylwester, 1987) as well as for Navy six-year obligors (Mackin, 1993). Smith, Sylwester and Villa (1991) used the ACOL-2 model to estimate pay elasticities for the reenlistment behavior of Army personnel. The average estimated pay elasticity for this study was 1.3. When mean promotion times were used to predict military compensation instead of promotion time models, the estimated pay elasticity for reenlistment increased to 1.7.

Each of these studies estimates retention-pay elasticities, defined as the percentage change in retention probability divided by the percentage change in military pay. Table 3 summarizes pay elasticity estimates produced in this literature.

Table 3
Enlisted Models and Empirical Results

Enlisted Studies	Service	YOS	Years Studied	Pay Elasticities
Smith, Sylwester and Villa (1991)	Army	3-11	FY 74-87	0.6-1.9
Daula and Moffitt (1995)	Army	3-11	FY 74-87	1.3-2.2
Enns, Nelson and Warner (1984)	All	4-16	FY 1977	0.33-2.71
Warner and Goldberg (1984)	Navy	3-10	FY 74-78	1.06-3.25
Mackin, Mairs, et. al. (1989)	All	4-12	FY 78-87	0.21-2.66
Mackin (1993)	Navy	1-6	FY 89-92	0.49-1.22
Mackin (1992)	Navy	3-15	FY 78-89	0.12-0.60

In addition to these general studies on retention pay elasticities, there have also been more specific studies that focused on how pay elasticities change at different career reenlistment points.

Retention by Quality of Individuals and by Military Branch

Davis et. al. (1988) tested whether the sensitivity of retention to pay varies over time, Service or quality using the ACOL model. They estimated an elasticity of 1.9 at first term reenlistment, 1.4 at second term reenlistment, and .4 at third term reenlistment for Army personnel. Pay elasticities for Navy personnel were 1.8, 1.3 and .4 for first term, second term and third term reenlistments respectively. The authors also found that, after controlling for differences in retention and pay by Service, Army members have lower predicted pay elasticities and that the estimated pay elasticities were larger for high-quality members; however, the differences are slight.[39]

The Effect of Pay on Retention, by Term of Reenlistment

Hosek and Peterson (1985) estimated a trichotomous logit model for first term and second term retention decisions using grouped service data where the choices were reenlist, extend or leave. The pay variable was an index of military relative to civilian pay–a specification unrelated to the random utility model of choice behavior used in the ACOL model. The authors estimated pay elasticities to be 3.8 for first term reenlistments and 1.7 for second term reenlistments.

Rodney et. al. (1980) used the basic ACOL framework modified to include two wage variables in the same equation. Results show a pay elasticity of 2.3 for first and second term Navy reenlistment decisions.

Black, Hogan and Sylwester (1987) used the ACOL-2 model to estimate pay elasticities for the reenlistment behavior of Navy personnel. This revised model explicitly controlled for the self-selection bias caused by unobserved heterogeneity. The estimated pay elasticities for this

[39]High quality individuals were defined as high school graduates in AFQT Categories I-IIIA.

study were lower than previously estimated: .95 for first-term reenlistment, .33 for second-term reenlistment and .27 for third-term reenlistment.

A number of other pay studies have produced pay elasticity estimates. Warner (1979) used a logit estimation of the ACOL model with grouped cross-sectional Navy data from YOS 4 through 16 and estimated first-term pay elasticities in the 2 to 3 range. Zulli (1982) estimated a sequential model for enlisted Navy personnel and found a pay elasticity of .64 for those reenlisting at the third decision point. Lakhani (1988)–as part of a study examining the cost effectiveness of reenlistment initiatives relative to soldier replacement–calculated pay elasticities for Army enlisted personnel. Elasticity estimates from this study are comparatively low, ranging from .08 for non-combat personnel to .2 for combat personnel,

Warner (1982) estimated a sequential logit version of the ACOL model for both first and second term reenlistment decisions in the Marine Corps using grouped data from FY 1977-78. Pay elasticity results ranged from 1-2 in the first term to 1-3 in the second term.

Other Reenlistment Elasticities: Loss of Spouse Income

Hogan (1990) analyzed the Army retention decision by focusing on the family as an economic decision-making unit. Hogan surmised that the loss in income from spousal unemployment or from reduced wages becomes an important consideration in the retention decision. Using a revised Annualized Cost of Leaving (ACOL) model which considers a spouse's income stream in the retention decision. Hogan estimated reenlistment elasticities. The estimated parameters imply that a $100 reduction in spousal income increases the probability of reenlistment by about 3 percent. This translates into a reenlistment rate elasticity of about -.12 with respect to other family income. In contrast. a $100 increase in the member's annual Army pay increases the probability of reenlistment by about 1 percent, suggesting a reenlistment elasticity with respect to the member's pay of about 1.3.

Table 4 summarizes elasticity estimates from these studies:

Table 4
Service Retention Studies for Enlisted Populations

Author	Branch	Elasticity	Comments
Hogan (1990)	Army	η_1: 1.30 η_2: -0.12	The first elasticity is the pay elasticity, and the second figure in the elasticity with respect to loss in spouse income
Goldberg & Warner (1982)	Navy	η_1: 2.35 η_2: 0.34	The first elasticity is the pay elasticity, and the second figure is the elasticity with respect to the time spent at sea
Hosek & Peterson (1985)		η_1: 3.80 η_2: 1.70	The first elasticity is the pay elasticity for first term reenlistments, and the second is the pay elasticity for second term reenlistments.
Rodney et. al. (1980)	Navy	2.30	Pay elasticities for both first and second term reenlistments were the same.
Warner (1979)	Navy	2-3	
Warner (1982)	Marines	η_1: 1-2 η_2: 1-3	η_1 represents the pay elasticity for first term reenlistments, and η_2 represents the pay elasticity for second term reenlistments.
Zulli (1982)	Navy	0.64	The figure represents the pay elasticity for third term reenlistments.
Lakhani (1988)	Army	0.20 0.08	The first figure is the pay elasticity for combat personnel, and the second figure is the pay elasticity for non-combat personnel.
Davis et al (1988)	Army	1.90 1.40 0.40	The first elasticity is the pay elasticity for first term reenlistment; the second is the pay elasticity for second term reenlistment; and the third figure is for third term reenlistment.
Davis et al (1988)	Navy	1.80 1.30 0.40	The first elasticity is the pay elasticity for first term reenlistments; the next figures are pay elasticities for second and third term reenlistments.
Black, Hogan & Sylwester (1987)	Navy	0.95 0.33 0.27	The first elasticity is the pay elasticity for first term reenlistments; the next figures are the pay elasticities for second and third term reenlistments.

Officer Models and Empirical Results

There has been less research conducted on officer retention behavior than there has been for enlisted groups. Gotz and McCall (1983) estimated a dynamic retention model for Air Force captains. The Gotz-McCall theoretic framework, like ACOL-2, explicitly controls for self-selection that occurs as retention rates rise with tenure. However, policy simulations are difficult to generate using the dynamic retention framework, and estimated parameters from this study were not published. (It was later "calibrated" for Air Force enlisted personnel by Arguden (1986)). Hogan and Goon (1989) estimated a simple ACOL model for Air Force officers by occupational specialty. They included other variables to control for censoring in the error structure inherent in ACOL and arrived at pay elasticities in the .3 to 1.1 range.

More recently, Mackin, Hogan and Mairs (1993) estimated an ACOL-2 model for Army officers. This study develops a multi-period model for Infantry and Signal Corps officers. Mackin, Hogan and Mairs (1995) also used the ACOL-2 model to estimate parameters for the Officer Personnel Inventory, Cost and Compensation (OPICC) model for Army officers. In this application, estimated pay elasticities fell into a similar but wider range compared with estimates from Mackin et. al. (1993). This wider range can, in part, be explained by the fact that different groups were studied in 1993 and 1994. The 1993 study was limited to Infantry and Signal Corps officers, while the 1994 sample consisted of all ACC officer branches included in the ARI's Officer Longitudinal Research Data Base. However, the main reason for variation in the pay elasticity estimates comes from the YOS range under investigation. The wider range of pay elasticities calculated in Mackin et. al. (1995) correspond directly to the wider YOS range (In the 1994 study, the lowest pay elasticity, .029, is for YOS 15 and the highest, .599, is for YOS 1. The 1993 study only includes YOS 3-11). Table 5 summarizes the pay elasticity calculations for officers:

Table 5
Officer Retention Literature

Authors	Service	YOS	Years Studied	Pay Elasticities
Gotz & McCall (1983)	Air Force	7-30	FY 1970	Not Reported
Hogan & Goon (1989)	Air Force	5-12	FY 76-88	0.3-1.1
Mackin, Hogan and Mairs (1993)	Army	3-11	FY 79-90	0.040-0.396
Mackin, Hogan and Mairs (1995)	Army	1-15	FY 79-92	0.029-0.599

Retirement and Retention

Most of the work to date on the retention effects of the military retirement system has been largely theoretical. A major reason for the dearth of empirical research stems from a lack of comparative data. Even after an alternative retirement plan is implemented, it takes a substantial period before retirement behavior–and reaction to changed incentives–can be accurately monitored.

Prior to 1981, few changes were made in the military's retirement system; consequently, data was not available for estimating the comparative retention effects inherent in the system. However, the recent changes in annuity calculations associated with the "High-Three" and "Redux" programs should offer the opportunity to estimate the marginal effects of retirement compensation. Since the 1981 cohort will not be eligible for regular retirement for another six years or so, it will take another decade before the full effects of the 1981 and 1986 changes in retention can be assessed. Data does currently exist to measure changes in retention rates for the first 14 years of the 1981 cohort and the first 8 years of the 1986 cohort–years for which the retention effects arising from changes in the retirement system are likely to have a significant impact. A few studies have attempted to predict retention rates under alternative retirement plans.

Warner (1979) predicts retention rates under retirement plans with different vesting points using four different models, PVCOL, ACOL, SCOL, and the Air Force-CBO Model. The ACOL-2 model, used by Mairs et. al. (1992), and the Dynamic Retention Model, used by Gotz and McCall (1983), further refined the theoretic framework by allowing estimation of effects resulting from unobservable characteristics of personnel.

Several sources contain information on retention in light of the recent policy changes affecting the retirement system. DoD (1992), Gansler (1989), Warner and Asch (1993), and Asch and Warner (1994) are good starting points. The QRMC report provides a broad overview of linkages between compensation (including retirement), performance, recruiting and retention based on a comprehensive literature review.

Early on, Gansler (1989) pointed out that the Redux system decreases the incentive to stay until the vesting point at YOS 20–since the size of the annuity is smaller–but should actually increase retention among the remaining cohort members after YOS 20 by increasing the pecuniary return to staying for an additional period. Gansler also suggested that military retirement is currently structured so that the Services are losing members before the optimal point: "more and more people have been retiring at about 40 years of age, depriving the services of their expertise and collecting retired pay for the rest of their lives" (pp. 297-298).

Warner and Asch (1993) discuss at length, in the context of policy reform, the main purposes of the retirement system. These include the "macro" goals, "to attract and retain personnel in sufficient numbers to meet its grade and experience requirements" and the "micro" goals, "to provide individuals with the proper incentives to work hard and seek advancement," and to "sort personnel effectively . . . into proper person/rank/job matches" (p. 7).

The long version of this paper (1994) develops a formal model of individual and organizational decision-making in the new military environment. The study, published by RAND's National Defense Institute, addresses all aspects of military compensation–not only retirement. Asch and Warner effectively synthesize the existing literature and incorporate the emerging economic theory of compensation and incentive links within hierarchical organizations. As with ACOL-2 modeling, they employ the utility maximizing framework and account for taste censorship. They also attempt to explain "effort supply" decisions under imperfect monitoring environments. Finally, the paper presents a generalized discussion of the decision making process faced by Service members under the current compensation and retirement systems and within the drawdown context.

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